Nova Scotia Research Foundation Corporation
Dartmouth, Nova Scotia

TECHNOLOGY IN ACTION

THE DEVELOPMENT OF AN IN-MINE
GEOPHYSICAL BOREHOLE LOGGING SYSTEM

for

The Science Branch
Science and Professional Services Directorate
Supply and Services Canada
(RFP 06SQ.23440-9-9197)

by

Nova Scotia Research Foundation Corporation (NSRFC)

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EXECUTIVE SUMMARY

This report describes a conceptual design for an In Mine Geophysical Borehole Logging System for use in underground coal mine exploration and pre-mine development particularly in multi-seam mining operations where surface access is difficult or expensive. The system is modular and each module (or its individual parts) will be explosion proof, intrinsically safe or certified for "special protection" or employs a combination of these regulatory requirements for safe operation in the coal mining environment.

A brief synthesis of the main units in the system includes the following:

Geophysical probes may be purchased directly from manufacturers for total gamma ray, gamma-gamma density) and neutron-neutron logging functions. These probes may require modification, specifically electronics, connectors and probe shells so that they are explosion proof, intrinsically safe or certified under the "special protection" category. The requisite vertical resolutions are unlikely to be achieved in these slimhole probes due to space limitations which restricts source-detector shielding and geometry together with the requirement of logging through BQ, NQ or HQ drill rods. Logging cable and cable head are available from the manufacturers.

The winch will be a modified light weight hoist with electronic depth indicator and line tension sensor. It will be driven hydraulically with control valves to give constant drum speed. A slip ring will pass the intrinsically safe probe power and cables. Hydraulic power will be supplied either by the diamond drill power pack or a portable hydraulic power pack with electric power supplied from the coal mine supply.

Above horizontal or horizontal geophysical logging will be carried out using a hydraulic pressurization method consisting of a water sub-system (Seal Tee assembly, water pump and water control manifold). The water pump will be powered by the winch hydraulic power supply. This will be a variation of existing methods.

The electronics module will be intrinsically safe. Data will be stored in integrated circuit memory and transferred, outside of the coal mine, to a personal computer at the end of each day's geophysical logging. Log displays will either be on liquid crystal or electroluminescent panels. A rechargeable lead-acid gel cell rechargeable battery in an explosion proof box will provide power for both electronics module and geophysical probes. A 6800 series CMOS processor will be adequate for the planned data accumulation rates. An alpha numeric touch panel is provided for operation of the electronic module and logging parameters.

The primary software function will be to acquire the nuclear probe statistical count data at 0.5 cm logging intervals and store them in random-access memory to provide the user with a real-time graphical data display and to transfer data to a separate personal computer.

The market study has indicated a small market for an explosion proof in-mine geophysical logging system with above horizontal logging capability of about 3 - 5 units. A number of existing systems and methods for logging horizontally and above the horizontal have been identified, but none fulfil all the specifications of the conceptual design presented in this report.

There is a good opportunity that specific parts of the system may find applications in other, related markets. A patent enquiry is required for the hydraulic pressurization method described in this report to ensure that it is different from existing patents.

Potential industrial partners were visited in Canada and identified by the marketing study. All require complete funding if only one unit is to be constructed and need concrete evidence of markets and profitability for a limited production version. Possible industrial partners in Canada include the Cord Group of Dartmouth, Nova Scotia, Computalog Wireline Products Inc. of Calgary, Alberta, Roke Oil Enterprises of Calgary, Alberta and Scintrex Ltd. of Toronto, Ontario. Possible US industrial partners include Comprobe Inc. of Fort Worth, Texas and Neltronic International Corp. of Houston, Texas. A consortium may be required to fulfil all aspects of this project.

The estimated total break even cost of producing one In Mine Geophysical Borehole Logging System as described in the conceptual design of this report is about $360,000.00 Canadian excluding applicable taxes. The estimated cost of spares for this unit is about $40,000.00 Canadian. These prices do not include the costs of subsequent upgrades or enhancements, operation, training, maintenance, consumables and repairs.

For a limited production of six units the estimated cost is about $150,000.00 Canadian per unit which includes a 30% mark up on each unit, again excluding applicable taxes. This price does include some monies for upgrade/enhancement of the first unit but, again, excludes operation, training, maintenance, consumables and repair costs.

We are recommending that a single unit be manufactured by a Canadian Industrial Partner for use by the Cape Breton Development Corporation. This unit could then be used as a demonstration system for marketing and sales and would allow the industrial partner to assess market size for a limited production run. The construction and demonstration of the unit will enhance and improve the capability of Canadian industry. If this venture is successful, the industrial partner should be given full and exclusive rights to the system design.

For the manufacture of a single unit we recommend that complete funding is provided for the industrial partner together with additional funds for an upgrade/enhancement of the system after about 6 - 12 months of completion of manufacture. Canadian industrial partners should have first opportunity to take up this project.

The Nova Scotia Research Foundation Corporation is recommended to act as client representative on the design/fabrication phase to follow the conceptual design described in this report and also to operate, maintain and repair the system for the Cape Breton Development Corporation.

If the design/fabrication phase does not take place, then an In Mine Logging System should be purchased from the German manufacturer with the 40 mm OD geophysical probes presently being designed.

2 INTRODUCTION

2.1 Project History

The need for a geophysical borehole logging system for use underground in the coal mines of Cape Breton was first brought to the attention of the Geophysics Division of the Nova Scotia Research Foundation Corporation (NSRFC) by Mr. S. Forgeron, Chief Geologist of the Cape Breton Development Corporation (CBDC) in 1982. At that time, a system was envisaged with a 600 feet (183 metres) hole depth capability to log inside an HQ drill hole (borehole diameter: 3.5 inches or 88.9 mm) with logging in open hole. The required probes would be total gamma ray and gamma-gamma (density) with the probability of caliper (borehole diameter) as a third probe. Sonic and shear wave measurements were discussed as possible future requirements. Logging vertically upwards from an existing tunnel to sample coal seams above the actively mined seam was also a stated requirement. Electrical power supplies from the coal mine (550 VAC, 3 phase) were envisaged as being adequate to power the logging system. Compressed air was discussed as an alternative power supply for the winch.

In 1982 it was known that no such system was in existence in North America. European demands were apparently satisfied by hand cranked surface systems with special dispensation for underground use. Further development was required for these systems.

During the period 1982 - 1986, the main efforts of the Geophysics Section, NSRFC were centred on marine geophysics equipment developments. Underground geophysical logging for the CBDC was carried out using the Geophysics Section surface logging unit in intake tunnels with continuous monitoring for methane during logging operations.

In 1986 revised specifications for an underground geophysical borehole logging system were drawn up by K. Howells and S. Forgeron.

A technical proposal for an In-Mine Borehole Logging System was prepared by K. Howells and J. Osborne in February, 1987 entitled "An Unsolicited Proposal for Phase I of the Design of an Explosion Proof Geophysical Borehole Logging System for Underground Use in Coal Mines". This was submitted to the Committee on Atlantic Coal in March, 1987 with a letter of support from the Cape Breton Development Corporation. Though the proposal was recommended by the Committee on Atlantic Coal, financial support was not available at that time. A visit to Ottawa by K. Howells confirmed this situation.

Further discussions between NSRFC and CBDC culminated in an updated proposal written by E. Smallhorn, K. Howells and J. Osborne in January, 1989 which was resubmitted to the Committee on Atlantic Coal. In January, 1990 an RFP was received from the Science Branch, Science and Professional Services Directorate, Supply and Services Canada (06SQ.23440-9-9197) for the "Development of an In-Mine Borehole Logging System". The NSRFC proposal was revised and costings redefined to address the RFP requirements. The proposal was submitted in February, 1990 and a revised version accepted in March, 1990 ("A Proposal for the Development of an In-Mine Borehole Logging System" by the Geophysics Section, Applied Science Division, NSRFC). The project began in April, 1990.

2.2 The Need for an Underground Geophysical Borehole Logger

The coal mines operated by CBDC extend offshore from the northeast coast of Cape Breton Island, Nova Scotia. The numerous coal seams found on land, in the onshore portion of the Sydney coalfield, are known to continue for large distances underwater between Nova Scotia and Newfoundland. The numerous mineable coal seams present in the coal basin form the reserves for multi seam mining operations. Coal exploration and pre-mine development require drilling ahead of mining operations normally carried out from the surface to test the quality and continuity of the coal, coal seam depth and thickness, the presence or absence of geological structures, such as folds, faults and meandering stream deposits within the coal bearing sediments, and geotechnical/engineering properties of the rocks. For the submarine coal deposits off Cape Breton, this would require drilling from very expensive marine platforms such as drill ships and drill rigs.

However, where undersea mining is already in progress, coal seams above and below the actively mined seam may be sampled underground by drilling upwards or downwards from the worked seam. Though cores are retrieved of the coal section, the recovery is frequently only 20 - 50% from the coal seams. This poor recovery is due to the presence of methane gas under pressure in the coal and the numerous small joints and cracks ("cleats"). Drilling into a coal seam relieves the pressure and the coal frequently "explodes", breaking up into numerous small pieces. Hence, the cores do not provide a complete sample of the seam and true depths and thicknesses are difficult to estimate.

Geophysical logging does provide complete physical measurements through coal seams. Low gamma ray counts and low density compared to the surrounding sediments (eg: sandstones, siltstones and shales) identify the coal seam and allow measurement of coal seam thickness and depth. Hence, geophysical logs in these underground boreholes are an essential part of the coal exploration and pre-mine planning process.

2.3 Preliminary Specifications for an In-Mine Logging System

The following preliminary specifications were drawn up for the conceptual design of an In-Mine Geophysical Logging System and are as included in the RFP:

2.3.1 Meets the requirements of the Canadian Explosives Atmospheres Laboratory and Labour Canada for operation in underground coal mines.

2.3.2 Is of adequate strength and ruggedness to function reliably in active mining environments.

2.3.3 Is able to drill intermediately in any places from vertically upwards to vertically downwards.

2.3.4 Is capable of logging boreholes of lengths 305 meters (1,000 feet).

2.3.5 Includes total gamma ray, density or gamma-gamma and neutron-neutron methods.

2.3.6 Measures with the probes passing inside drill rods and/or casing sizes HQ, NQ or BQ.

2.3.7 Optimizes a geophysical probe source to detector spacing such that seam locations and thickness can be measured with an accuracy of ± 3 cm (± 1.2 in) for gamma-gamma and neutron-neutron logs.

2.3.8 Borehole logging probe speeds will be approximately 2 metres/minute (detailed logs) or 6 metres/minute (total hole logs).

2.3.9 The logging system must be portable. A modular system, with each module transportable by two persons will be acceptable. This corresponds to a module weight of about 50 Kg.

2.3.10 Geophysical logs will be reproduced in analog form using a suitable device.

Note: Item 2.3.3 is interpreted as a requirement to be able to drill in any direction from vertically upward to vertically downward.

2.4 Explosion Proof, Intrinsically Safe or Equipment Certified on the Basis of "Special Protection"

For safe operation in a coal mine, all equipment must be made explosion proof, intrinsically safe or certified on the basis of "special protection". A system, such as the in-mine geophysical borehole logging system may consist of individual modules or units which may employ any of the above three categories to satisfy the requirements of the regulatory agencies.

Potentially explosive mixtures of air (oxygen) and methane gas (over a range of concentrations of 5 - 15%) are known to occur in coal mines at various times. If ignition occurs, secondary explosions are caused by suspended coal dust and are known to be more damaging than the initial methane explosion.

Temperatures greater than 500°C are required to ignite an air-methane mixture. Such temperatures may be generated by the striking together of rusted iron or steel and aluminum, titanium or magnesium. Most mining equipment uses steel in its construction. Hence, it is the other metals that must not be used for the external parts of mining equipment. Note that most surface geophysical logging units use aluminum for winch construction and most of the electronic modules are housed in aluminum containers. Otherwise unacceptable metals may be allowed if thickly coated with zinc or equivalent.

An electrical spark above a certain energy level or a wire (or similar component) heated above the ignition temperature is also a potential explosion trigger. Explosion proofing (or flame proofing) of the equipment is used to eliminate this danger. Equipment which is explosion proof contains potentially hazardous electrical/electronic circuits in housing with strong walls and carefully designed joints and apertures so that the any internal explosion resulting from an air-methane mixture is safely contained. Cables and connectors must also meet rigorous standards. The result of explosion proofing is heavy, cumbersome equipment which requires meticulous and frequent maintenance.

An alternative is to design equipment to be intrinsically safe. This approach requires that no electrical/electronic circuit can generate a spark or thermal effect capable of triggering an explosion. This must be the case even under specified fault conditions. Prescribed test strategies are required to guarantee that the design objectives have been met. Once the design has been approved, it cannot be modified in any way. Intrinsically safe equipment is lighter and less cumbersome than explosion proof equipment but still requires frequent and meticulous maintenance.

A third method is to have the equipment certified on the basis of "special protection". The equipment is neither intrinsically safe nor explosion proof but is nevertheless a recognized method of protection in which design features, which do not fit into the explosion proof and intrinsically safe categories, are considered to be safe. It is based on the premise that equipment can be made safe by employing combinations of other methods of protection.

Bossert and Hurst (1986) is a comprehensive introduction to this aspect of mining equipment design which lists various specifications in use in Canada and other countries. The Canadian specifications form part of the Canadian Electrical Code (1990). It must be emphasized that this aspect of the equipment design is of paramount importance in that it is essential for the safe operation of coal mines and the safety of mine personnel.

2.5 Coal Mine Equipment Operating Conditions

Coal mine equipment operating conditions were experienced first-hand by project personnel on an underground visit to a working coal mine in the Sydney coal field of Cape Breton. A visit was arranged to the CBDC Phalen Mine on 19 April 1990, by Mr. S. Forgeron. This mine extends underwater for about 2 km and has a sloping entrance on land immediately adjacent to the coast.

Project personnel were transported underground by "rake" (mechanized railway on an inclined slope which is lowered and raised by cable). The harsh underground operating conditions were observed at a working retreat long-wall face and in tunnels away from the production area. Explosion-proof and intrinsically-safe electrical equipment used in the coal mine was examined which included cabling, junction boxes, transformers, electrical switches and control boxes. The relatively high temperatures and humidity in the coal mine were noted. An underground drill, set up in an unused roadway to drill holes for rock stress measurements, was examined. Methods of keeping coal dust to a minimum including wetting and dust barriers were observed.

After the visit, a laboratory demonstration of an air-methane explosion was given by the scientific authority, Mr. Dan Kennedy, in the CANMET Coal Research Laboratory in Sydney, Nova Scotia. From these visits, it was obvious that robust and reliable geophysical borehole logging equipment was needed which is explosion-proof, intrinsically-safe or has "special protection" certification or a combination of all three to satisfy the stringent mine equipment regulatory process.

3 PROBLEM DEFINITION

The development of any product can be broken down into phases. A typical phase hierarchy, with outputs, is:

Design Phase	Output
Conceptual Design	Concept
Preliminary Design	Model
Detailed Design	Prototype
First Production	Finished Product

Each of these phases can have the steps as outlined in Figure 3.1.

This report covers the conceptual design phase of the development of an in-mine borehole geophysical logging system.

This section of the report (Section 3: Problem Definition) addresses the first six steps of the conceptual design under headings shown in Figure 3.1.

3.1 Needs Analysis

3.1.1 A means of collecting geophysical data for geological analysis of the material in the vicinity of an underground mined area. Specifically, to measure the depth and thickness of coal seams

3.1.2 A means of collecting this data without the requirement for drilling from the surface.

3.1.3 A means of collecting this data safely in coal mines.

3.1.4 A means of expanding Canadian expertise in mining.

3.1.5 A means of encouraging the growth of the Canadian mining industry.

3.1.6 A means of stimulating the participation of Nova Scotia in the Canadian mining industry.

3.1.7 To produce a conceptual design to meet the above needs.

3.2 Objectives

3.2.1 To produce a conceptual design of a system which will:

3.2.1.1 Geophysically log a borehole oriented in any direction and originating from inside a coal mine passageway. (See 3.1.1, 3.1.2, 3.1.3)

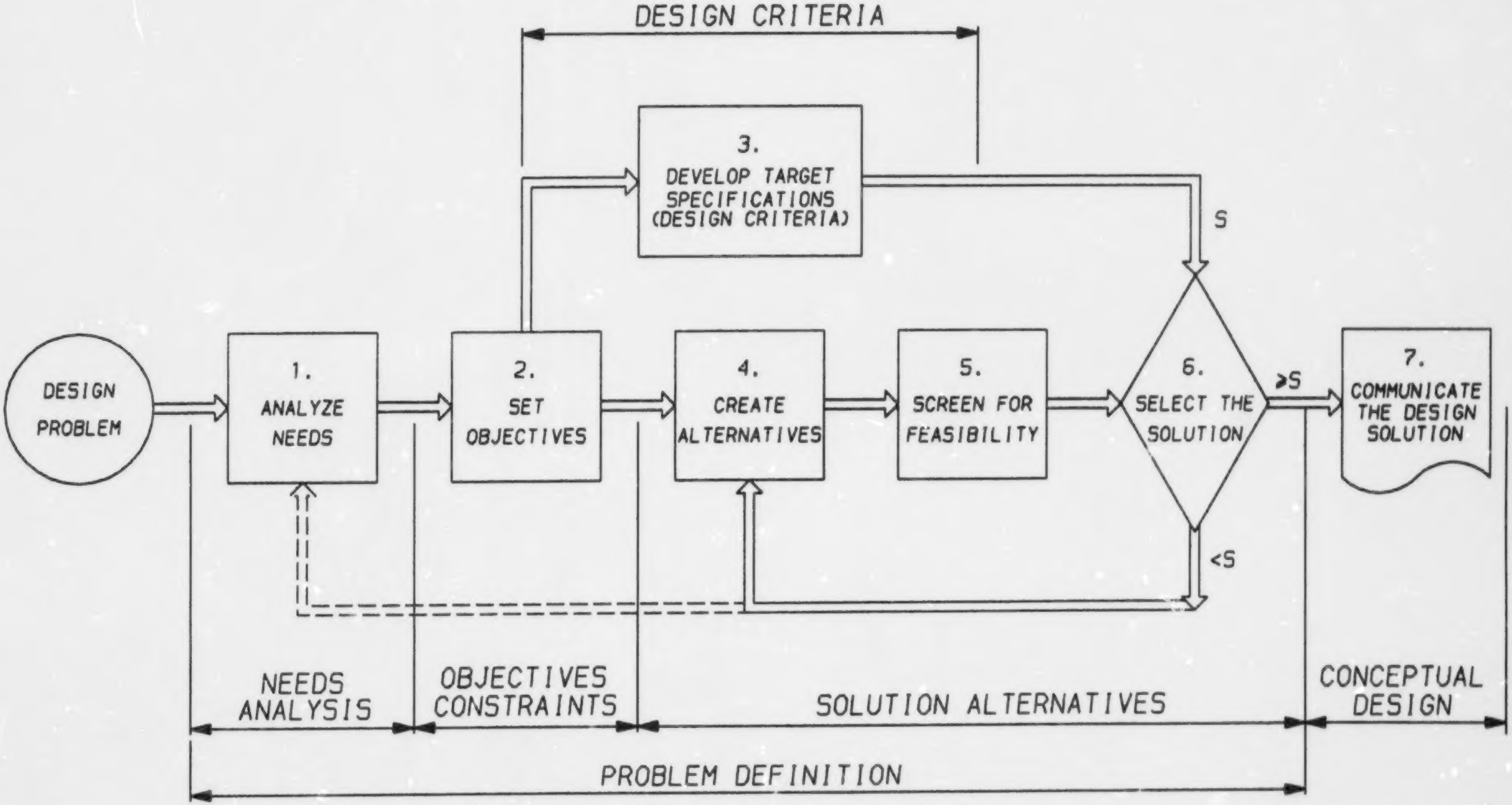

DESIGN CRITERIA
DESIGN PROBLEM
1. ANALYZE NEEDS
2. SET OBJECTIVES
3. DEVELOP TARGET SPECIFICATIONS (DESIGN CRITERIA)
4. CREATE ALTERNATIVES
5. SCREEN FOR FEASIBILITY
6. SELECT THE SOLUTION
S
≥S
<S
7. COMMUNICATE THE DESIGN SOLUTION
NEEDS ANALYSIS
OBJECTIVES CONSTRAINTS
SOLUTION ALTERNATIVES
CONCEPTUAL DESIGN
PROBLEM DEFINITION

FIGURE 3.1

3.2.1.2 The production unit cost should be no more than that of an equivalent capability standard surface unit plus the added costs of explosion proofing and uphole logging and generally making the system suitable for use in a coal mine.

3.2.1.3 A production unit should be available for surveys in January 1992 (design/construction of a production unit will take 12 months).

3.2.2 To attract the interest of industrial partners through presentation of the concept and the results of a marketing study. (See 3.1.4, 3.1.5, 3.1.6)

3.3 Constraints

3.3.1 "To Geophysically Log a Borehole" means to be able to make the following geophysical measurements:

3.3.1.1 Total Gamma Ray
3.3.1.2 Gamma-Gamma (Density)
3.3.1.3 Neutron-Neutron

3.3.2 "Oriented in any Direction" means radially outwards from a line parallel to or including the axis of the mine passageway in a plane which is orthogonal to the axis or which makes an angle up to 45° with the axis. (See Figure 3.3.2)

3.3.3 "Inside a Coal Mine" means the equipment must meet the following standards for use in coal mines:

3.3.3.1 Canadian Explosive Atmospheres Laboratory
3.3.3.2 Labour Canada
3.3.3.3 Canadian Standards Association (CSA)

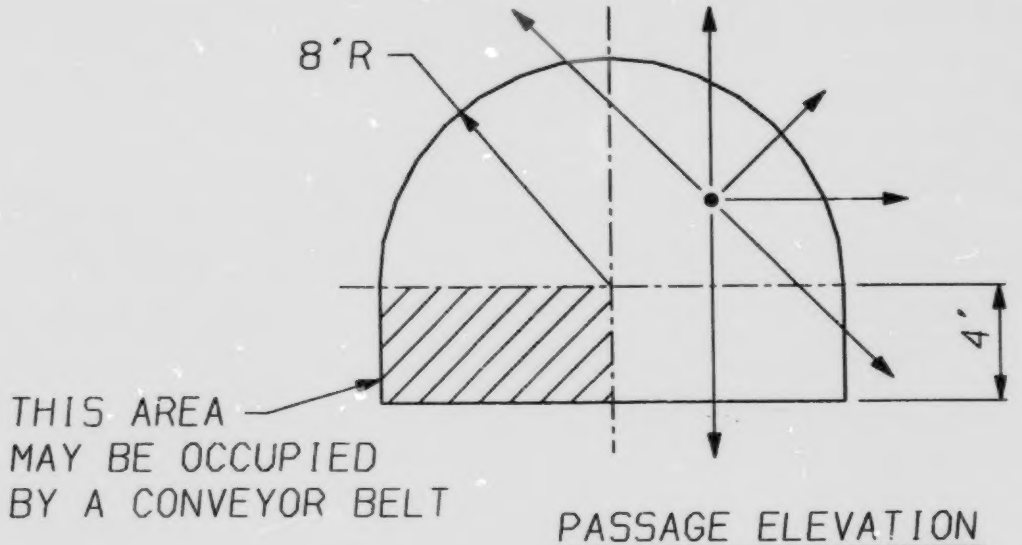
3.3.4 "Originating Inside a Coal Mine Passageway" implies the clearances around the borehole entrance are defined by the dimensions of the mine passageway and any structures supporting the walls and any mine equipment (eg: conveyor belt system). See Figure 3.3.2. If the logging must be done through the drillhead, the clearances will be affected by the dimensions of the drilling equipment. See brochure on Longyear 38 EHS drill.

3.3.5 To operate, the system must require no more than one geophysical operator and two men to carry equipment.

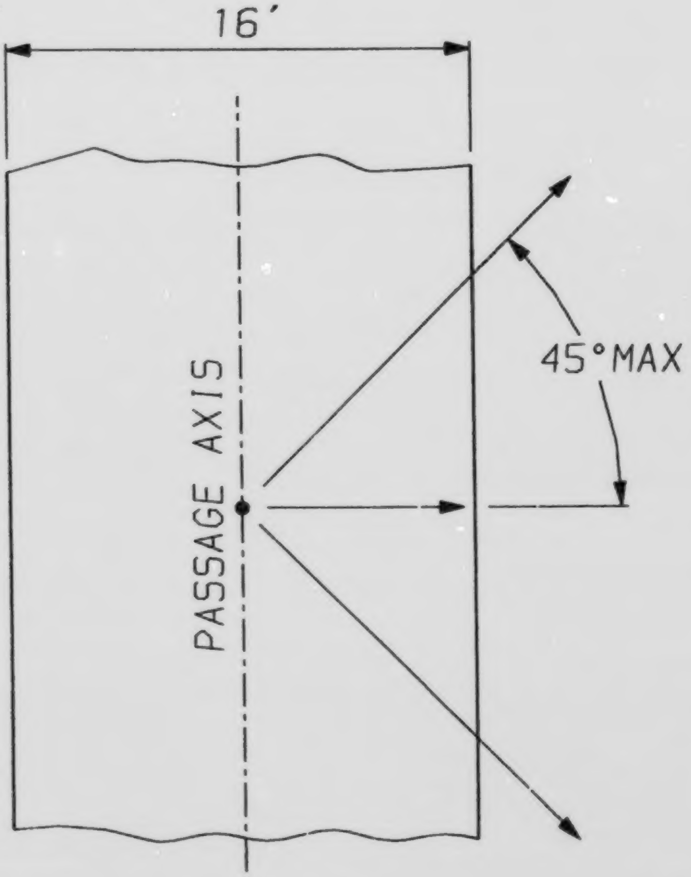
3.3.6 The preferred origin of the industrial partner is, in order of preference: Nova Scotian, Canadian, other.

3.3.7 The industrial partner must be in a position and have the intent to commercialize the concept.

Figure 3.3.2


8′R
4′
THIS AREA
MAY BE OCCUPIED
BY A CONVEYOR BELT

PASSAGE ELEVATION


16′
PASSAGE AXIS
45°MAX

PASSAGE PLAN

3.3.8 "Borehole" means holes up to 305 meters (1000 feet) long and lined with drill pipe or casing in the size range BQ to HQ (see Table 1).

3.3.9 The equipment must be of adequate strength and ruggedness to function reliably in active mining environments.

3.3.10 Coal seam boundary depths and thickness must be measurable within ± 3 cm (± 1.2 inches)

3.3.11 Logging speeds shall be approximately:

3.3.11.1 2 m/min (6 ft/min) for detail logs.
3.3.11.2 6 m/min (20 ft/min) for total hole logs.

3.3.12 The system must be portable by manpower. A modular system with each module transportable by two persons is acceptable. Maximum module weight ≤ 50 kg.

3.3.13 The geophysical logs must be available, in graphical form, for immediate viewing at the hole site.

3.4 Design Criteria

3.4.1 Geophysical Probes: General Probe Parameters

3.4.1.1 High resolution (gamma-gamma/density and/or neutron-neutron) probes may be equipped with a decentralizer if necessary to maintain contact with the inside of the drill rod. Note that the decentralizer will not be required for horizontal or above-horizontal logging and will be such that it is retracted flush with the probe shell.

3.4.1.2 The total length of a probe assembly shall be ≤ 5 ft. (152.4 cm) (due to available clearances).

3.4.1.3 The probe pressure rating shall be not less than 34,500 kPA (5000 PSI).

3.4.1.4 The diametral clearance between the O.D. of the probe casing and the I.D. of the drill rod through which it must pass shall be 0.813 to 0.513 inches (20.7 to 13.0 mm). This will restrict the outside diameter of a geophysical probe to a maximum of approximately 1.3 inches (33 mm).

3.4.1.5 The probe shall be compatible with the method used for moving it into the hole where this method does not rely on gravity.

3.4.1.6 All probes shall be explosion proof or intrinsically safe or certified on the basis of "special protection" type Ex(s).

Table 1

Diamond Coring Bits
Q Wireline Diamond Bits

Size	CORE DIAMETER (inches)		HOLE DIAMETER (inches)		HOLE VOLUME (U.S. gal. per 100 feet)
	Decimal	Fractional	Decimal	Fractional	
AQ, AQ-U	1.062	1-1/16	1.890	1-57/64	14.6
BQ, BQ-U	1.432	1-7/16	2.360	2-23/64	22.7
NQ, NQ-U	1.875	1-7/8	2.980	2-63/64	36.3
NQ2"	1.990	2	2.980	2-63/64	36.3
HQ, HQ-U	2.500	2-1/2	3.782	3-25/32	58.3
PQ	3.345	3-11/32	4.827	4-53/64	95.1
BQ-3	1.320	1-5/16	2.360	2-23/64	22.7
NQ-3	1.775	1-25/32	2.980	2-63/64	36.3
HQ-3	2.406	2-13/32	3.782	3-25/32	58.3
PQ-3	3.270	3-9/32	4.827	4-53/64	95.1

Size	CORE DIAMETER (mm)	HOLE DIAMETER (mm)	HOLE VOLUME (L/100 m)
AQ, AQ-U	27.0	48.0	181.0
BQ, BQ-U	36.5	60.0	282.2
NQ, NQ-U	47.6	75.7	451.0
NQ2"	50.5	75.7	451.0
HQ, HQ-U	63.5	96.0	724.4
PQ	85.0	122.6	1180.4
BQ-3	33.5	60.0	282.2
NQ-3	45.0	75.7	451.0
HQ-3	61.1	96.0	724.4
PQ-3	83.0	122.6	1180.4

Table 1 (Continued)

Wireline Drill Rods
Q Wireline Drill Rods

Size	OD (inches)	ID (inches)	Weight (lb/10 ft)	Threads per inch	Content (U.S. gal. per 100 feet)
AQ	1-3/4	1-3/8	31	4	7.7
BQ	2-3/16	1-13/16	40	3	13.4
NQ	2-3/4	2-3/8	52	3	23.0
HQ	3-1/2	3-1/16	77	3	38.2
PQ	4-5/8*	4-1/16	106**	3	67.4

Size	OD (mm)	ID (mm)	Weight (kg/3 m)	Threads per inch	Content (L/100 m)
AQ	44.5	34.9	14.0	4	95.8
BQ	55.6	46.0	18.0	3	166.3
NQ	69.9	60.3	23.4	3	285.8
HQ	88.9	77.8	34.4	3	474.4
PQ	117.5*	103.2	47.2**	3	836.6

* Coupling OD
** With Coupling
PQ Rod Body OD = 4 1/2 inches = 114.3 mm

3.4.1.7 Bare aluminum or its alloys or any other metals and their alloys which are unsafe for use in coal mines shall not be used on any external surfaces of the probe assembly.

3.4.1.8 The probe power requirement must not exceed 10 watts, typically 24 VDC and 0.2 AMPS.

3.4.1.9 The probe weight shall not be greater than 10 kg (22 lbs).

3.4.1.10 The probe operating ambient temperature shall be in the range: -20 to +90°C (-4 to +194°F).

3.4.1.11 The probe-cable head connector shall be of the Gearhart 1 - 4 type.

3.4.2 Geophysical Probes: Sources, Sensors and Electronics

The probes shall contain the following sources and sensors with the other described features:

3.4.2.1 Total or Natural Gamma Ray Probe

This probe may be an analog or digital unit.

The sensor will be an omnidirectional scintillometer consisting of a Thallium doped Sodium Iodide (NaI(Tl)) crystal or equivalent and a photomultiplier.

The crystal dimensions will be such that a sufficient volume of rock external to the borehole is sampled so as to minimize the effect of the borehole and its fluids, drill rods and/or casing. Adequate vertical resolution must also be obtained.

This probe will be centred in the middle of the borehole/drill rods.

The response of this probe must be linear over a range of 1 to 500 counts per second (cps).

The probe must be calibrated in API units. An API field calibration unit must be supplied with the probe for a minimum range of 0 to 200 API units.

The probe must be calibrated prior to shipping and calibration results supplied with the probe. The calibration should include the effects of the variation in borehole diameter, drill rods and a water filled hole or correction tables. The dead time of the analog total gamma ray system must be < 1µ second.

The analog gamma ray probe must incorporate the following or equivalent electronic circuitry: preamplifier, discriminator, pulse shaper, and power amplifier.

The digital gamma ray probe must incorporate the following or equivalent electronic circuitry: preamplifier, discriminator, counter and digital transmission units.

3.4.2.2 Gamma-Gamma or Density Probe

This probe may be an analog or digital unit.

The sensor will be a scintillometer consisting of a Thallium doped Sodium Iodide (NaI(Tl)) crystal or equivalent and a photomultiplier.

The crystal dimensions will be such that a sufficient volume of rock external to the borehole is sampled so as to minimize the effect of the borehole and its fluids, drill rods and/or casing. Adequate vertical resolution must also be attained.

The gamma ray source will consist of Caesium^{137} or equivalent (663 keV) and will be of sufficient intensity so that Compton Scattering is the main process by which the gamma radiation is backscattered in the rocks adjacent to the borehole.

The lower cut off energy threshold for the backscattered gamma rays shall be such that the effects of photoelectric reactions are eliminated or minimized.

The probe will be of the single scattering (collimated), dual spaced density or diffusion type system.

The probe will be decentralized with a bowspring for downhole logging.

The probe response must be linear over a range of at least 1 to 25,000 cps.

The probe must be calibratable directly in density units (gm/cc). Secondary calibration units must be supplied with the probe for a range of densities from 0.5 gm/cc to 3.00 gm/cc in suitable increments. The probe must be calibrated prior to shipping and the calibration results supplied with the probe. The calibration should include the effects of the variation in borehole diameter, drill rods in a water filled hole or correction tables for these effects. Secondary calibration units need to be constructed such that drill rods may be inserted and the simulated borehole filled with water or tables supplied with appropriate corrections for these effects.

The dead time of the analog gamma-gamma system must be < 1μ second.

The analog gamma-gamma probe must incorporate the following or equivalent electronic circuitry: preamplifier, discriminator, pulse shaper and power amplifier.

The digital gamma-gamma probe may incorporate the following or equivalent electronic circuitry: preamplifier, discriminator, digital processing, counting and transmission units.

A gamma ray source storage/transportation unit and a source handling device (for inserting and removing the radioactive source from the probe) must be supplied. Both source storage/transportation unit and source handling device must satisfy the appropriate Canadian safety and transportation regulations.

3.4.2.3 Neutron-Thermal Neutron Probe

This probe may be an analog or digital unit.

The sensor will be a Helium^3 proportional counter or equivalent. It will sample a sufficient volume of rocks external to the borehole so as to minimize the effect of the borehole and its fluids, drill rods and/or casing. Adequate vertical resolution must also be attained.

The neutron source will be Americium^{241} Beryllium, linear accelerator or equivalent.

The probe will be either omnidirectional, single scattering (collimated), dual spaced or of the diffusion type.

If non-omnidirectional, the probe will be decentralized with a bowspring for downhole logging.

The probe response must be linear over a range of at least 1 - 2500 cps.

The probe must be calibratable directly in porosity units (%). Secondary calibration units must be supplied with the probe for a range of porosities from 0 to 100% in suitable increments. The probe must be calibrated prior to shipping and the calibration results supplied with the probe. The calibration should include the effects of the variation in borehole diameter, drill rods in a water filled hole or correction tables for these effects. Secondary calibration units need to be constructed such that drill rods may be inserted and the simulated borehole filled with water or tables supplied with appropriate corrections for these effects.

The dead time for the analog neutron-neutron probe must be such that undercounting does not take place or is minimized within the appropriate count range.

The analog neutron-neutron probe must incorporate the following or equivalent electronic circuitry: preamplifier, discriminator, pulse shaper, de-randomizer and power amplifier.

The digital neutron-neutron probe must incorporate the following or equivalent electronic circuitry: preamplifier, discriminator, digital processing, counting and transmission units.

A neutron source storage/transportation unit and a source handling device (for insertion and removal of the radioactive source from the probe) must be supplied. Both source storage/transportation unit and source handling device must satisfy the appropriate Canadian safety and transportation regulations.

3.4.3 Cable

3.4.3.1 The cable shall be 335 m (1100 feet) long.

3.4.3.2 The cable shall have a working strength of not less than 230 kg (506 lbs).

3.4.3.3 The cable shall have an O.D. compatible with the method of moving the probe up the hole.

3.4.3.4 The cable shall contain the number and type of conductors to satisfy the probe requirements.

3.4.3.5 Each conductor shall have a resistance not greater than 26 ohms per 300 m and a capacitance to all other conductors not exceeding 200 pf/m.

3.4.3.6 The cable shall have a rugged, round, wear resistant, watertight, double armoured external strength member.

3.4.3.7 The cable armour electrical resistance shall not exceed 8 ohms per 300 metres of length.

3.4.3.8 The cable shall be acceptable for in-mine use.

3.4.3.9 The cable shall have a weight not exceeding 61 lbs/1000 ft.

3.4.3.10 The cable conductor inductance shall not exceed 0.5 microhenries per metre.

3.4.4 Probe Interface Digital Circuitry

The circuits will be digital in design to process the signals from the analog or digital probes as they appear at the cable head.

The digital circuits will include an accumulating register or equivalent. The electronics will be buffered.

3.4.5 Winch

3.4.5.1 Power

3.4.5.1.1 The winch shall be driven by an electric or hydraulic motor.

3.4.5.1.2 If electric, the winch drive shall require 110 VAC, 1 phase supply.

3.4.5.2 Line Speed

3.4.5.2.1 Logging shall be carried out while winching in or out. Therefore the winch shall have a logging in or out speed range of 0 to 10 m/min (0 to 32.8 feet/min. Commonly used speeds in this range are:

1 - 2 m/min (6.56 feet/min) for detail logs
6 m/min (19.68 ft/min) for logs over the entire borehole.

3.4.5.2.2 The winch shall be capable of passively paying out at constant speed and actively winching in at constant speed. The maximum pay out and retrieve speed shall be 46 m/min (151 ft/min).

3.4.5.2.3 Speed shall be constant and accurate to ± 0.1 m/min (± 0.33 ft/min) at logging speeds and ± 2 m/min (± 6.56 ft/min) at retrieve speed.

3.4.5.3 Line Tension

3.4.5.3.1 The winch shall be capable of applying 100 kg (220 lbs) line tension at logging in and retrieve speeds.

3.4.5.3.2 The winch shall be capable of applying as low as 5 kg (11 lbs) line tension at pay out speed.

3.4.5.3.3 The winch shall be capable of applying an adjustable maximum line tension limit in the range 100 to 150 kg (220 to 330 lbs).

3.4.5.4 Controls

3.4.5.4.1 The winch shall have a manual emergency stop control.

3.4.5.4.2 The winch shall have a cable position sensor suitable for interfacing with the instrumentation unit. Accuracy of this line out sensor shall be 0.25 cm (0.098 inch).

3.4.5.4.3 The winch shall have a line in limit control for stopping the line before the probe is pulled clear of the hole. This control shall be independent of the interface unit.

3.4.5.4.4 The winch shall have a braking capability with an adjustable maximum holding line tension of 100 to 150 kg (220 - 330 lbs).

3.4.5.5 The winch shall have a slip ring assembly compatible with the cable.

3.4.5.6 The winch assembly shall be compatible with the standards for in-mine use.

3.4.5.6.1 There shall not be any bare aluminum or titanium or related alloys exposed on its outer surfaces.

3.4.5.6.2 If the drive is electric, it shall be explosion proofed to mine standards.

3.4.5.7 The winch shall not create any electromagnetic noise which disturbs the log signal.

3.4.5.8 The winch shall have a cable tension measuring device with local output.

3.4.5.9 The winch with cable shall have a weight not exceeding 50 kg.

3.4.5.10 The winch shall be able to be conveniently carried by two men.

3.4.5.11 The winch drum diameter shall not be less than 25.4 cm (10 inches).

3.4.5.12 The winch shall be rugged enough to survive impacts corresponding to a drop of 500 mm either vertically upright or either end at an inclination of 40 degrees.

3.4.6 Active Probe Insertion

3.4.6.1 Active probe insertion system denotes the hardware system required to move the probe into the hole without relying on gravity.

3.4.6.2 The system shall function in all hole orientations for which gravity is inadequate to move the probe into the hole.

3.4.6.3 The system shall be capable of being easily added to or removed from the logging system to allow quick changes from gravity to active probe insertion and vice versa.

3.4.6.4 The active insertion system shall allow controlled centralization or decentralization of the probe.

3.4.6.5 Changing from one probe insertion system to the other shall not require the disconnection of the probe from the cable.

3.4.7 Electronics Module

3.4.7.1 The electronics module shall perform the following functions:

- 3.4.7.1.1 Supply power to internal electronics, probe and cable position sensor.
- 3.4.7.1.2 Condition the signal from the probe and cable position sensor.
- 3.4.7.1.3 Receive and process operator input.
- 3.4.7.1.4 Record signal and organizational data onto internal memory.
- 3.4.7.1.5 Display logs in graphical form in real time and from memory.
- 3.4.7.1.6 Download memory contents to the post processing unit via serial or parallel link.
- 3.4.7.1.7 Convert 120 V.A.C. power to recharge the internal battery.

3.4.7.2 The inputs to the electronics module shall be:

- 3.4.7.2.1 Cable position sensor
- 3.4.7.2.2 Probe signal (one of three probe outputs)
- 3.4.7.2.3 Keyboard commands

3.4.7.2.4 Power

3.4.7.3 The outputs from the electronics module shall be:

3.4.7.3.1 Probe power (one of three probe inputs)

3.4.7.3.2 Display

3.4.7.3.3 Serial data

3.4.7.3.4 Parallel data

3.4.7.3.5 Cable position sensor power

3.4.7.3.6 Analog chart drive

3.4.7.4 Data storage memory shall be sufficient to contain data from one day's logging with headers, branch headers and footers for each log and calibration parameters.

3.4.7.5 The module shall be explosion proof or intrinsically safe to mine standards.

3.4.7.6 The module shall be able to be conveniently carried by two men.

3.4.7.7 The module weight shall not exceed 50 kg.

3.4.7.8 The equipment shall remain undamaged during normal air, ground and in-mine transportation.

3.4.7.9 The equipment shall remain functional if either or both ends are dropped while being man-carried. This corresponds to a drop of 500 mm either vertically face up or on either end at an inclination of 40 degrees.

3.4.7.10 The electronics module shall be water tight and dust tight for operation in an underground mining environment.

3.4.7.11 Operating temperature shall be 5 to 35°C.

3.4.7.12 Storage/transportation temperature shall be -10 to 40°C.

3.4.7.13 The operating relative humidity range shall be 0-60% when the electronics module is opened to the atmosphere at the surface (outside of the coal mine).

3.4.8 Software for the Logging System

3.4.8.1 The logging software shall perform the following functions:

3.4.8.1.1 Interface with the user through a display and keyboard.

3.4.8.1.2 Log probe signal versus probe position.

3.4.8.1.3 Store the log data and identification in solid state memory (RAM).

3.4.8.1.4 Transfer contents of memory to an IBM-compatible PC.

3.4.8.1.5 Transfer log data or memory contents via a digital-to-analog converter to an analog output.

3.4.8.2 The logging software shall have the following features:

3.4.8.2.1 Provision for setting and adjusting the hole depth datum and offset.

3.4.8.2.2 Provision for setting "logging start" and "logging stop" cable positions (hole depths).

3.4.8.2.3 Provision for adjusting or maintaining probe signal within range while logging is proceeding.

3.4.8.2.4 Provision for inputting probe-specific settings before a run.

3.4.8.2.5 Provision for displaying logs in real time.

3.4.8.2.6 Provision for displaying logs from memory (up to three logs side by side on display screen).

3.4.8.3 User Interface

3.4.8.3.1 Communication with the system shall be via a keyboard/panel with standard "QWERTY" layout.

3.4.8.3.2 A menu structure and/or prompts shall permit access to all of the data logger's functions.

3.4.8.3.3 Allowable inputs shall be:

- Header data
- Footer data
- Logging start cable position
- Logging stop cable position
- Cable position offset and datum
- Display parameters
- Logging parameters

- Set-up parameters
- Calibration parameters
- Logging stop
- Logging resume
- Request for log catalog
- Request for log display
- Request for header display
- Request for footer display
- Request to abort logging run

3.4.8.3.4 The outputs shall be:

- Completed header for checking catalog of logs stored in memory (see Figures 3.3, 3.4 and 3.5).

- Real time graphical display of log in progress with named axes and grid (see Figures 3.3, 3.4 and 3.5).

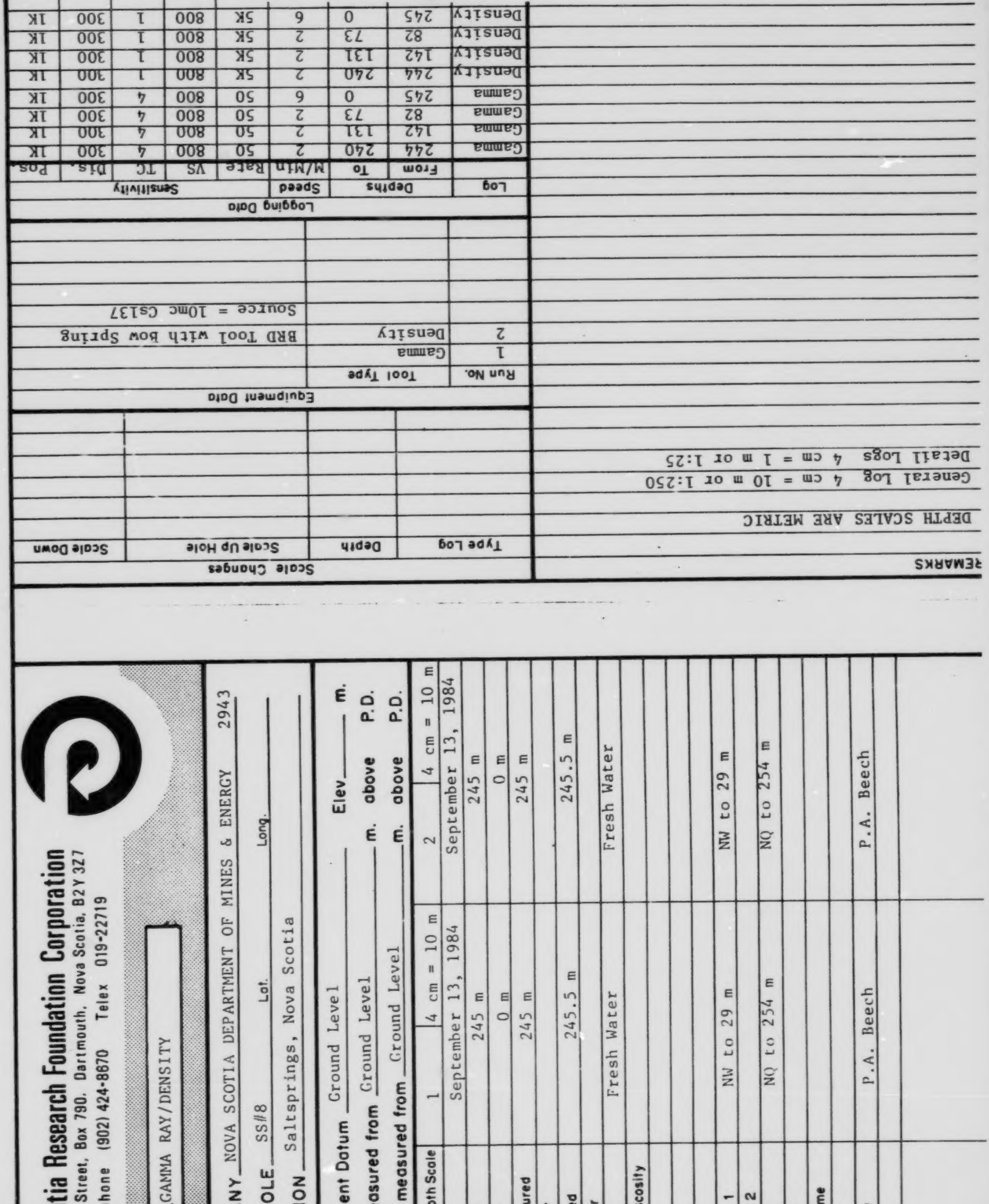
- Graphical display of completed logs with named axes and grid with capability to display up to three logs side by side on display screen.

- Error/warning messages.

3.4.8.3.5 Header data shall be associated with each set of log data and shall consist of:

- File name
- Date and time of log
- Borehole identification
- Calibration data for each probe i.e., counts per second versus API units (total gamma ray), density units (gamma-gamma probe), and porosity units (neutron-neutron probe).
- Logging tool parameter data including tool serial number.
- Other information and format as in Figures 3.3, 3.4 and 3.5.

3.4.8.3.6 Footer data shall be associated with each set of log data and shall consist of user entered comments. These comments can be added by the user during a run and are appended to the end of the log data set.



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GAMMA RAY/DENSITY

COMPANY NOVA SCOTIA DEPARTMENT OF MINES & ENERGY 2943
BOREHOLE SS#8 Lat. Long.
LOCATION Saltsprings, Nova Scotia

Permanent Datum Ground Level Elev. m.
Log measured from Ground Level m. above P.D.
Drilling measured from Ground Level m. above P.D.

Run No. / Depth Scale	1 / 4 cm = 10 m	2 / 4 cm = 10 m
Date	September 13, 1984	September 13, 1984
First Reading	245 m	245 m
Last Reading	0 m	0 m
Interval Measured	245 m	245 m
Casing Driller		
Depth Reached	245.5 m	245.5 m
Bottom Driller		
Mud Nature	Fresh Water	Fresh Water
S.G. / Viscosity		
Bit Size 1		
2		
3		
Casing Size 1	NW to 29 m	NW to 29 m
2		
Rod Size 1	NQ to 254 m	NQ to 254 m
2		
Operating Time		
Truck No.		
Recorded By	P.A. Beech	P.A. Beech
Witness		

REMARKS

DEPTH SCALES ARE METRIC

General Log 4 cm = 10 m or 1:250
Detail Logs 4 cm = 1 m or 1:25

Scale Changes

Type Log	Depth	Scale Up Hole	Scale Down

Equipment Data

Run No.	Tool Type	
1	Gamma	
2	Density	BRD Tool with Bow Spring
		Source = 10mc Cs137

Logging Data

Log	Depths		Speed	Sensitivity				
	From	To	M/Min	Rate	VS	TC	Dis.	Pos.
Gamma	244	240	2	50	800	4	300	1K
Gamma	142	131	2	50	800	4	300	1K
Gamma	82	73	2	50	800	4	300	1K
Gamma	245	0	6	50	800	4	300	1K
Density	244	240	2	5K	800	1	300	1K
Density	142	131	2	5K	800	1	300	1K
Density	82	73	2	5K	800	1	300	1K
Density	245	0	6	5K	800	1	300	1K

Figure 3.3

Figure 3.4

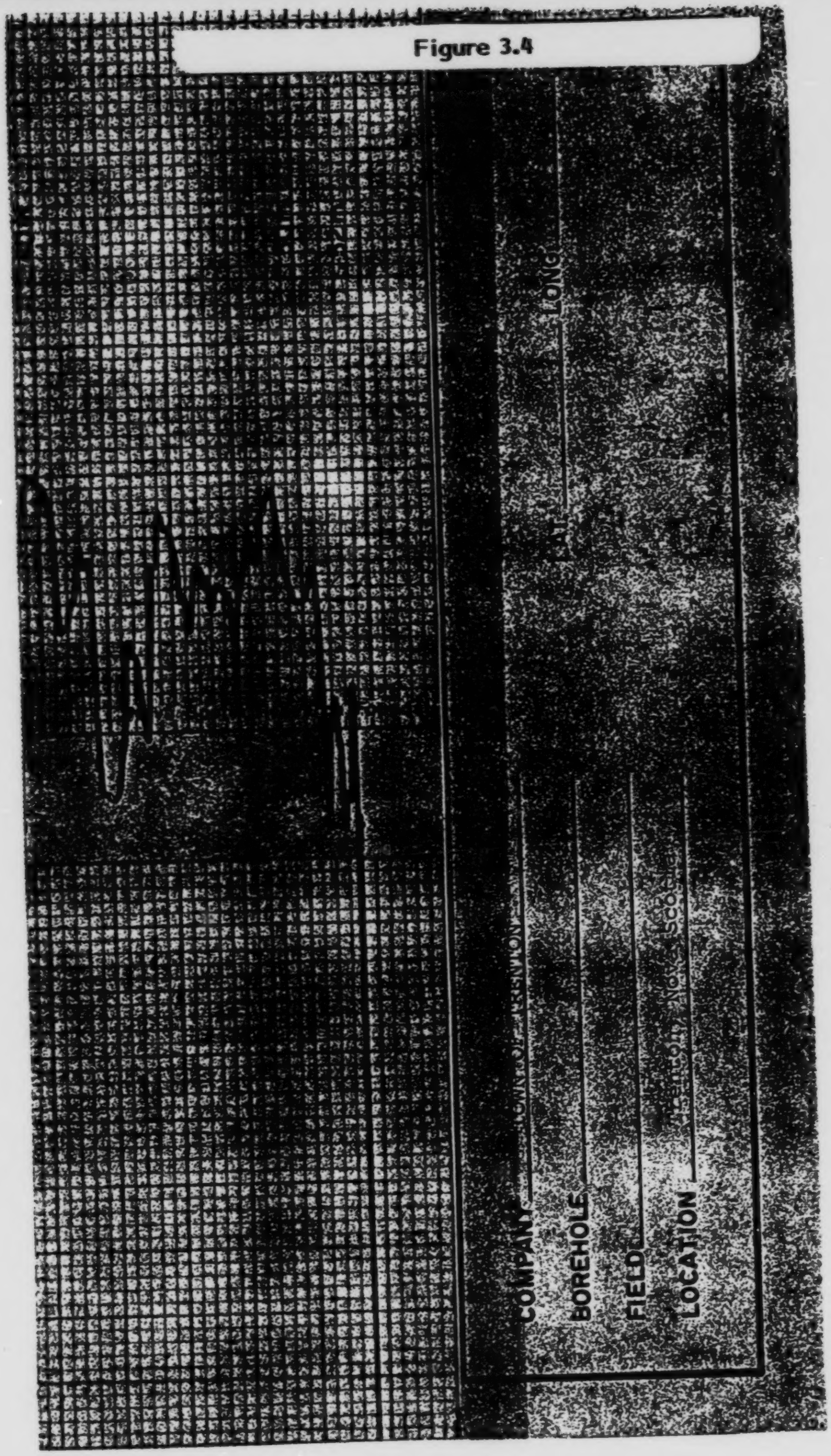
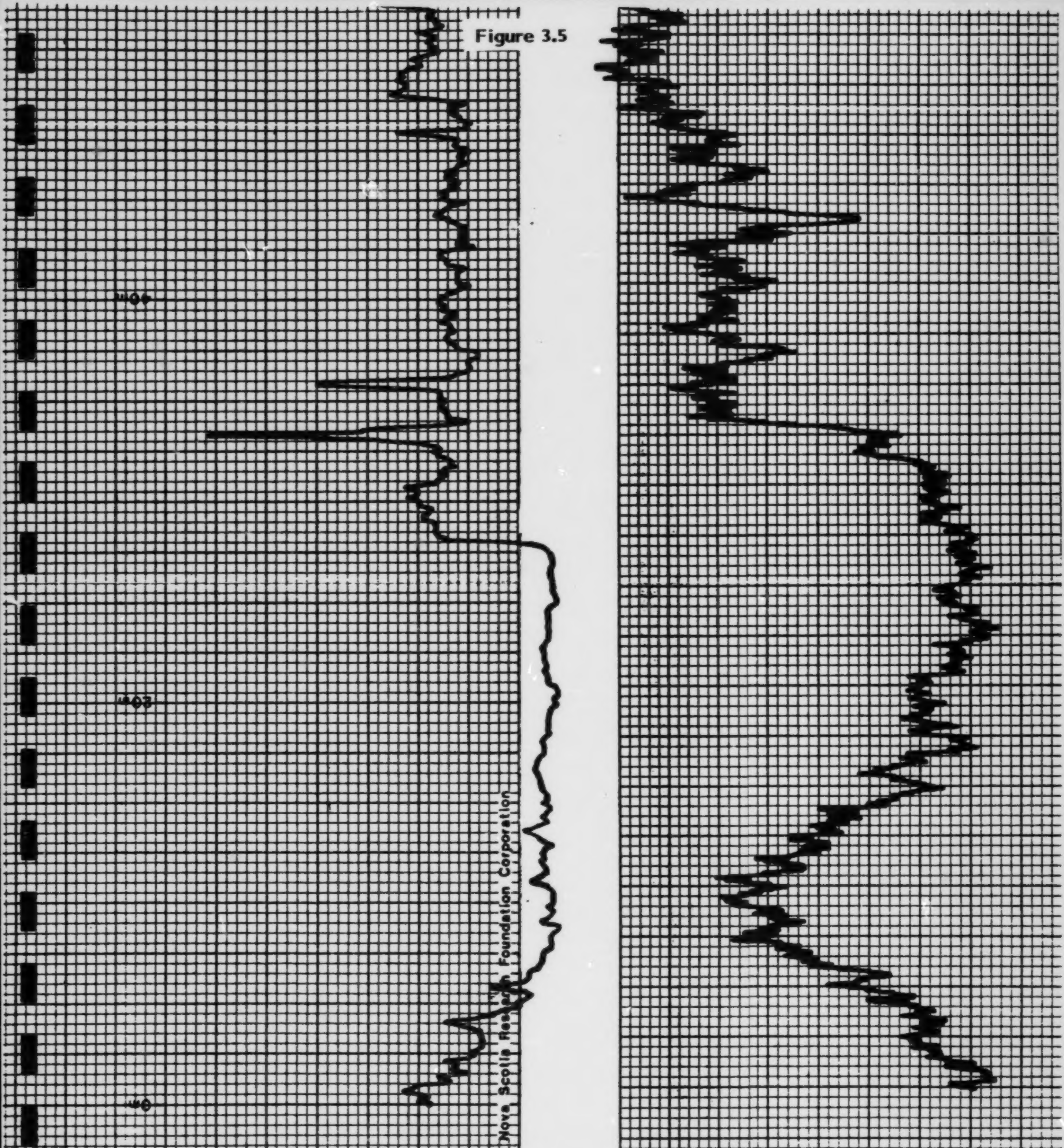


Figure 3.5


DENSITY CALIBRATION C.P.S.
0
1K
2K
3K
4K
5K
6K
7K
GAMMA CALIBRATION C.P.S.
10
20
30
40
50
60
0m
20m
40m
Nova Scotia Research Foundation Corporation

3.4.8.3.7 Logging Start/Stop Cable Position

The logging of data shall automatically start and stop when the probe reaches the positions specified by these parameters which may be over ridden manually.

3.4.8.3.8 Cable Position Offset and Datum

The software shall have provision for defining the current probe position as zero or some other positive or negative number.

3.4.8.3.9 The display parameters to be specified by the user shall be:

- Depth scale for all displayed logs.
- Log amplitude scale including maximum and minimum values for each of up to three displayed logs.
- Horizontal position of each of up to three displayed logs.

3.4.8.3.10 The logging parameters to be specified by the user shall be at least the following:

- Signal input range for each probe in counts/second.
- System dead time.
- Time constants for nuclear probes.

3.4.8.3.11 The user shall be able to specify set up parameters by calling a parameter file or by creating a new parameter file. The parameter list shall contain at least the following:

- Probe type
- Probe output signal
- Correction factors
- Offsets

3.4.8.3.12 The software shall have provision for calculating a tool calibration to determine the calibration parameters. These can then be entered at run-time.

3.4.8.3.13 Logging Stop/Resume

The software shall suspend data acquisition on the probe signal when the winch stops and resume data acquisition when it restarts. An override command is also required so as to carry out static probe tests and calibrations.

3.4.8.3.14 The software shall have a provision for viewing a catalog of the logs in memory.

3.4.8.3.15 The software shall have a provision for viewing the header or footer of any log in memory and a newly created header.

3.4.8.3.16 The software shall have provision for aborting a run and of stopping a log, doing a fast move to another depth and restarting the log without the loss of data.

3.4.8.4 Data Logging

3.4.8.4.1 The software shall sample the probe signal for every 0.5 cm probe position.

3.4.8.4.2 Automatic depth correction shall be provided for the probes to be used with the system.

3.4.8.4.3 The length of cable shall be logged and displayed at all times whether or not a probe is attached.

3.4.8.5 Log Storage

3.4.8.5.1 The software shall be able to store at least 20 log files in RAM.

3.4.8.6 Data Transfer

3.4.8.6.1 The software shall be able to transfer the data files in RAM to an IBM-Compatible PC via a serial port at 9600 Baud and a parallel port at a higher rate. The software shall also be able to generate an analog output using a digital-to-analog so giving an output for an analog chart recorder.

3.4.9 Post Processing Unit (PPU)

3.4.9.1 The PPU shall be an IBM-compatible personal computer with colour monitor and graphic printer.

3.4.9.2 The PPU shall be suitable for a normal office environment. It should be capable of being transported by air or road vehicle if suitably packaged.

3.4.9.3 The PPU shall be fitted with 2 MB of RAM, one 40 MB hard drive, and one each 3 1/2 inch and 5 1/4 inch floppy drives.

3.4.9.4 The PPU shall include an RS232 input port with 9.6 Kilobaud capability for transferring data from the Instrumentation Unit.

3.4.9.5 The PPU shall incorporate a high speed data transfer capability compatible with that of the Instrumentation Unit.

3.5 Solution Alternatives

The creation of alternatives which will meet the objectives is a necessary step in the design process. This project requires two basic objectives to be met. One involves the selection of a feasible hardware solution (Objective 3.2.1) and the other involves a means of meeting the first objective while making the best contribution to the Canadian economy, ie: having the system designed and built by an industrial partner (Objective 3.2.2).

3.5.1 Attracting Industrial Interest

Two approaches were used here: presentation of the concept in person to selected manufacturers, and completion of a marketing survey.

3.5.1.1 The first approach was completed during this project with the following results: (see Appendix I for a complete trip report).

3.5.1.1.1 Scintrex, Concord, Ontario - This company would not be interested in an in mine logger as part of their product line until after the prototype development stage. Even then they are not especially interested since it is out of their area of interest. They would only include the in-mine logger in their product line if it was a proven system with well-defined market.

3.5.1.1.2 Terraplus Inc., Richmond Hill, Ontario - This company is a representative for ABEM, a Swedish geophysical equipment manufacturer. ABEM is very interested in the project in that they have recently produced a new geophysical logging system and are looking for applications and opportunities, including coal. Terraplus president, Claude Meunier, was under the impression that this project included funding for the prototype development stage.

3.5.1.1.3 Computalog Manufacturing, Calgary, Alberta - This company is interested in new ideas, but would not be interested in this project unless they perceived a clear market opportunity and funding.

3.5.1.1.4 Roke Oil Enterprises, Calgary, Alberta - This company and their associated company, Widco, have considerable experience in sales, leasing, rental, servicing, contracting and training with respect to slimhole logging equipment. Roke itself is a geophysical logging service company which has carried out some innovative research into many aspects of coal logging and has developed probes, electronics, winches and accessory equipment for its own use, i.e. the equipment developed has not been manufactured for sale to external clients. Roke has some experience in logging underground, but not in coal mines and has no experience in explosion proofing or making equipment intrinsically safe. They have carried out some above-horizontal logging with push rods and hydraulic methods. Roke has the potential to be an industrial partner and is interested in this project. The company would require a Confidentiality and Licensing Agreement to protect their existing technology.

3.5.1.1.5 Summary of Visit to Canadian Manufacturers - For a summary of the visits to potential Canadian manufacturers/industrial partners, see Appendix 1.

In summary it appears that these Canadian companies are not interested in taking any risk in developing an addition to their product lines in the absence of positive marketing data or funding for the entire project.

3.5.1.2 The second approach was to obtain marketing data. The conclusions of the Marketing Study are given at the end of Section 5 in this report.

This study was not able to accurately quantify the potential for an in-mine geophysical borehole logging system, but does suggest a small market for approximately 3 - 5 units. However, it may be that market demand would increase if a system were available at a satisfactory price.

It must be pointed out that such a system is presently available in Germany. This system has the capability of logging upwards in an open borehole and, presumably, inside drillrods. However, though it is explosion proof/intrinsically safe it does have some limitations. The main problem is probe diameter which is 60 mm (2.36 inches) for the available gamma ray and gamma-gamma probes with the system. A neutron-neutron probe is not available at the present time. This probe diameter is too large for logging inside BQ or NQ drill rods and for logging in open holes drilled with BQ and NQ drillrods, Hence, either slimmer probes would have to be purchased from a different manufacturer and incorporated in the system or the system probes redesigned. Both alternatives would be expensive in terms of hardware and labour. Also, the system utilizes a double winching unit which may be cumbersome to use. The system would also have to be approved for use in Canadian coal mines.

The marketing study also concludes that there may be a number of barriers to the market for the system described in this report due to national boundaries, government control of coal mining in various countries, different mining safety legislation, existing systems as described in the previous paragraph and that the purchase price of our system is, as yet, not well defined. However, it must be noted that there may be additional applications for this equipment in other industries (eg: minerals, environment and hydrocarbons) and the market may be larger than anticipated.

3.5.1.3 Selection of a Hardware Solution

In selecting the hardware solution, three areas must be considered:

- The ability of the solution to perform standard logging functions.
- Explosion proofing of the system (see section 2.4).
- Active probe insertion capabilities of the system (logging above horizontal holes).

It is the last two which make the solution resulting from this project different from other borehole logging systems.

The following is an outline of the thinking that went into an assessment of feasibility and selection of a solution for each of the major system components defined in the design criteria.

3.5.1.4 Geophysical Probes

3.5.1.4.1 There are a number of solution alternatives for the geophysical probes required in the specifications for the In Mine Borehole Logging System. These alternatives include the following:

1. Conceptual designs are produced for each of the three probes (total gamma ray, gamma-gamma/density and neutron-neutron) and presented in the report with detailed design, construction and testing in the second phase of the In Mine Project.

2. Probes are purchased from probe manufacturers and made explosion proof, intrinsically safe or certified for "special protection" by the system manufacturer.

3. Probes are purchased from probe manufacturers and made explosion proof, intrinsically safe or certified for "special protection" by the probe manufacturer. This alternative would require direction and inspection by the system manufacturer.

4. Probes are purchased from the system manufacturer who would also be responsible for making them explosion proof, intrinsically safe or certified for "special protection".

Slimhole probe design and manufacture is a specialized industry with only a few manufacturers in Canada and the USA. As would be expected, many of the details of probe design and construction are proprietary and little or no information is given in many of the probe manufacturer's brochures and equipment listings as shown in Table 2. Probe design and manufacture does not lie within the areas of expertise of the design team for this project, though we do have experience in the modification, servicing and repair of geophysical probes. To maintain costs at a reasonable level, the solution alternatives are selected from 2, 3 or 4, ie: probes are purchased "off the shelf".

To this end, the Design Constraint listings were sent to the following five North American geophysical probe manufacturers:

1. Neltronic International Corporation, Houston, Texas

2. Roke Oil Enterprises Ltd., Calgary, Alberta

3. Computalog Wireline Products Inc., Fort Worth, Texas

4. EGG Geometrics, Mount Sopris Division, Sunnyvale, California

5. Comprobe Inc., Fort Worth, Texas

Some comments are required on the selected geophysical probe manufacturers. First, it is practical to assume that the selected probe manufacturer is likely to be Canadian or American in that these are the most accessible in terms of distance and would utilize North American hardware components. Second, that for the explosion proofing, intrinsic safety or "special protection" certification, regulations are likely to be very similar in Canada and the USA. Third, that we are proposing that the system manufacturer is based in Canada.

TABLE 2
TOTAL GAMMA RAY PROBES: MANUFACTURER'S SPECIFICATIONS

Item	Roke	Stratalog	Comprobe	EGG/Mount Sopris
Model		T75		
Outside Diameter	1", 1 1/4" (25, 32 mm)	1.3" (33 mms)	0.875, 1.0, 1.25, 1.375" (22.2, 25.4, 31.8, 34.9 mm)	
Length		44.88 " (1140 cm)		
Weight		3.25 kg (7.15 lbs)		
Pressure Rating		34,500 KPA (5000 PSI)	5,000, 15,000 PSI (34,500 KPA, 103,500 KPA)	
Temperature Rating		-10 to +60 or +100°C	225°F, 300°F (107.3°C, 149°C)	
Power at Probe		Nominal 20 VDC/40 mA	+120 VDC/60 mA negative pulse	30 VDC
Detector Type	NaI(Tl)	NaI	NaI	NaI(Tl)
Detector Size		12.7 x 44.5 mm (0.5 x 1.75")	0.5 x 3.0" (12.7 x 76.2 mm) 0.5 x 2.5" (12.7 x 63.5 mm)	22 x 76 mm (0.875 x 3.0")
Crystal Efficiency				
Photomultiplier		Housed in Shock Resistant Plug		
Top Sub Connection		Standard Gearhart 1 or 4		
Max Operating Cable Length		2000 m (6600 ft)		
Gamma-Ray Cut Off Frequency	70 keV			
Calibration	API field calibrator	API field calibrator	200 API field calibrator	
Pressure Housing	"Low Z" (Titanium)			
Probe Construction	Stainless Steel	Stainless Steel		
Dead Time	-	Constant. Provided on request		
Response		Linear 0 - 50,000 CPS		
Joins		Threaded/pressure sealed 2 'O' rings		
Inner Body		Acetal		
Special Features				

TABLE 2 (Continued)
TOTAL GAMMA RAY PROBES: MANUFACTURER'S SPECIFICATIONS (Continued)

Item	WBK	Computalog	Robertson Geologging Ltd.	ABEM
Model	In Log			
Outside Diameter	60 mms (2.36")	1" (25.4 mms)	38 mm (1.5")	
Length	1270 - 1790 mms (50 - 70.5")		2.12 m	1130 mms
Weight	12.2 - 17.6 kg		7.6 kg	4.3 kg
Pressure Rating		15,000 PSI (103,500 KPA)	3000 PSI or 5000 PSI	
Temperature Rating		375°F (190.7°C)	70 or 125°C	
Power at Probe	+5 v/3.5 w -5 v/0.5 w		80 VDC	1 Watt
Detector Type	NaI	NaI	NaI(Tl)	NaI
Detector Size	1 x 2" (25.4 x 50.8 mms)		50 x 25 mms	1 x 1.5" (25.4 x 38.1 mm)
Crystal Efficiency			70%	
Photomultiplier	1 1/8" (28.6 mm) high temp bialkali photocathode			
Top Sub Connection			4 conductor	
Max Operating Cable Length	800 m (2625 ft)			
X-Ray Cut Off Frequency				
Calibration			Ra^{226} 10µ Cijig	
Pressure Housing				
Probe Construction				
Dead Time				
Response				1 - 100,000 CPS
Joins				
Inner Body				
Special Features	Rise time + transit time for photomultiplier < 100 ms. Power supply module in probe 7 x 2.5 amperchours NiCd batteries (8 hour operation). Flame proof enclosure: EEX dI (ib). DPS-800 processor in probe with special interface board which includes two 16 bit counters with adjustable trigger level (software controlled by DPS-800).			

TABLE 2 (Continued)
GAMMA-GAMMA (DENSITY) PROBES: MANUFACTURER'S SPECIFICATIONS

Item	Stratalog	Roke	Robertson Geologging Ltd.
Outside Diameter	33 mms (1.3")	43 mms 1 11/16"	50 mms (1.9685")
Length	1320 mms (52 ins) - no spacers		2.79 m + 0.15 m = 2.94 m (9.65 feet)
Weight	4.5 kg (9.9 lbs) - no spacers		20 kgs
Pressure Rating	34500 kPA (5000 PSI)		3000 PSI (option 5000 PSI)
Temperature Rating	-10°C → 60°C	-20°C to +90°C (-4°F to 194°F)	70°C (option 125°C)
Power at Probe	Nominal 20 volts DC 40 mA		80 VDC
Detector Type	NaI (Tl)		High Sensitivity Scintillation NaI(Tl)
Detector Size	12.7 x 44.5 mms (0.5 x 1.75")		50 x 25 mms; 70% efficiency
Photomultiplier			
Probe Dead Time	Electronic dead time is constant. Figures provided on request.		
Top Sub Connection	Standard Gearhart 1 or 4 contact		
Max Operating Cable Length	1000 metres (3300')		
Source Storage Container Dimensions	W = 185 mm (7.3")		
Source Storage Container Weight	Portable density source storage container of lead and steel. Construction for Caesium source to conform with all applicable regulations		
Source Detector Spacing	200 mms (short) ≈ 8"		14 cms (5.5")
Resolution	≈ 8" (20.3 cms)	30 cms	14 cms (5.5")
Decentralizing	Bowspring	Bowspring	
Source Type	50 millicuries (1.85 GBq)C_e^{137}	125 millicuries ?C_e^{137}	100 millicuries C_e^{137}
Collimation	Yes	Yes Directional	Source & Detector are Tungsten Collimated
Detector Shielding	Yes	Yes	
Calibration	Factory density curve cps v gms/cc. Low value radioactive source. Field calibration blocks calibrator.		Al + Mg block calibrators
Linear response	Yes: 0 - 50,000 cps	Flat response curve to densities of 3.0 gms/cc	
External Fittings	Stainless Steel		
Internal Shielding and Focusing	Suitable shielding shall be fitted to reduce backscatter effects and to provide high accuracy in focusing of the source and shielding of the detector	8" depth of investigation. Response ratio (high to low counts) > 10:1. Front to back ratio of 40 to 1. Graded gamma ray filter to minimize effects of heavy minerals. Maintains accurate calibration to between 1.0 and 1.2 gms/cc. Time drift (1 year) = 2%.	

TABLE 2 (Continued)
GAMMA-GAMMA (DENSITY) PROBES: MANUFACTURER'S SPECIFICATIONS (Continued)

Item	Comprobe	Computalog	EGG/Mount Sopris	Sondex	ABEM	WBK
Outside Diameter	1 1/4" (31.8 mms)	1", 1 3/8" (25, 35 mm)		1 11/16" (42.9 mms)	42 mm	2.36" (60 mm)
Length	29.5" (74.9 cms)		149.4 cms		1400 mm	1270 - 1790 mm
Weight	5 lbs (2.27 kg)		5.0 kg (11 lbs)		8.8 kg	12.2 - 17.6 kg
Pressure Rating	5000 PSI				150 bar pressure rating	
Temperature Rating	225°F (107.3°C)				0 - 70°C	150°C
Power at Probe					1 Watt (maximum 25 watt)	7 * 2.5 AhNiCd
Detector Type						NaI(Tl)
Detector Size						5.08 x 2.54 cm (2" x 1")
Photo-multiplier						Photomultiplier Diameter 2.858 cm (1.125")
Probe Dead Time						Rise time + transit time < 100 ns
Top Sub Connection						
Max Cable Operations Length						
Source Storage Container Dimensions						
Source Detector Spacing	2" (5.08 cms)		20 cms (7.87")			18 cms (7.09")
Resolution	5.08 cms		20 cms			18 cms
Decentraliza-tion	Yes		Bowspring			
Source Type	50 mCi Am^{241}	C_s^{137}	5 mCiC_s^{137}		3 - 100 mCiC_s^{137}	555 Mbq C_s^{137}
Collimation					Shielding Material: Tungsten	45°
Detector Shielding						
Calibration						
Linear Response					Range 1-10 gms/cc	
External Fittings						
Calibration						

TABLE 2 (Continued)
NEUTRON-THERMAL NEUTRON PROBES: MANUFACTURER'S SPECIFICATIONS

Item	Stratalog	Roke	Robertson*	WBK	Sondex
Outside Diameter	34 mms (1.3")	1", 1 1/4" or 1 11/16" (25, 32, 43 mm)	38 mm (1.5")	Does not manufacture neutron-neutron	Does not produce slimhole neutron eg: sidewall neutron 4.25" OD 15000 PSI 320°F (160°C)
Length	1330 mm (51")		Source + 0.28 m, 2.12 m (6.96')		
Weight	4.5 kg (9.9 lbs)		10 kg (22 lbs)		
Pressure Rating	34500 kPA (5000 PSI)		3000 PSI (5000 option)		
Temperature Rating	-10 → +60°C		70°C (125°C option)		
Power at Probe	Nominal 20 VDC at 40 mm		80 VDC nominal		
Detector Type	Helium^3 Proportional Counter	He^3	He^3 proportional		
Detector Size	25 x 152 mm (1" x 6")		Detector Length 24 cms length (9.45")		
Photomultiplier			Tube pressure 4 atmos efficiency 90%		
Probe Dead Time	Constant - on request				
Top Sub Connector	Standard Gearhart 1 or 4 contact		1 or 4 conductor		
Max Cable Length	2000 m (6600')				
Source Type	1 curie (37 GBq) Americium Beryllium	Am^{241}Be	AmBe 1 Ci		
Source Detector Spacing	320 mms (12.6")		45 cms (17.72")		
Resolution	32 cms		45 cms		
Collimation	None		None		
Decentralization	Bowspring		Not described		
Source Storage	W 400 mms (16") H 400 m (16") L 400 m (16") 40 kg (88 lbs) Conforms to Heath Dept. regulations and meets IATA shipping requirements.		Yes		
Calibration					
Probe Linear Response					
External Fittings	Stainless steel				
Joins	Threaded & Pressure sealed with two "O" rings				
Inner Body	Acetal				

TABLE 2 (Continued)
NEUTRON-THERMAL NEUTRON PROBES: MANUFACTURER'S SPECIFICATIONS (Continued)

Item	ABEM	EGG/Mount Sopris LLP-2676	Comprobe	Computalog
Outside Diameter	No neutron probe manufactured at present. Planned for near future		7/8, 1.0, 1 1/4, 1 3/8" (22.2, 25.4, 31.8 or 34.9 mms)	1", 1 3/8" (25, 35 mms)
Length				
Weight				
Pressure Rating				15 K or 17 K PSI
Temperature Rating				375°F (188°C)
Power at Probe				
Detector Type		He^3		He^3
Detector Size			He^3 in stainless internal flask	
Photomultiplier				
Probe Dead Time				
Top Sub Connection			Single Conductor	
Max Cable Length				
Source Type		1 - 3 curie $Am^{241}Be$	1.2, 3.5 or 5 curie AmBe	$Am^{241}Be$
Source Detector Spacing		35 cms (13.8")		
Resolution		35 cms		
Collimation		No collimation		
Decentralization		Not described	Bowspring	
Source Storage		Yes	4 foot neutron source handling tool. Acrylic cube.	
Calibration				
Probe Linear Response				
External Fittings				
Joins				
Inner Body				

Two other manufacturers may also be considered in the eventuality that none of the products from the above is considered satisfactory; these are:

6. WBK, Bochum, Germany

7. Stratalog Pty Ltd., Brisbane, Australia

As described previously, WBK does manufacture digital, explosion proof probes for its In Mine Geophysical Borehole Logging System. However, as also pointed out in a previous section, their probe diameters (60 mm) precludes them from the present conceptual design unless they can be redesigned with an appropriate outside diameter (less than 35 mm). Presently, WBK does not have a neutron-neutron probe in its suite of probes.

Stratalog Pty Ltd. does manufacture all three specified probes for a surface logging unit, i.e.: they are not explosion proof, intrinsically safe or certified for "special protection". Stratalog provides good descriptions of its probes (Table 2) but has not been selected as a probe manufacturer mainly due to distance, which would increase travel and communication costs compared with North American manufacturers.

Of the five manufacturers listed above (1 to 5) to whom the design criteria were transmitted, negative responses were received from Computalog Wireline Products Inc. and EGG Geometrics. These negative responses are explained by Computalog Wireline Products manufacturing mostly larger diameter probes for oil/gas exploration and production holes; EGG Geometrics is a large company and does not appear to be interested in small, specialized applications as required by the In Mine Logging Project.

Positive responses were received from Comprobe Inc., Neltronic International Corp. and Roke Oil Enterprises Ltd.

1. Comprobe Inc., Fort Worth, Texas

Comprobe supplied descriptions of an ADP-2 Analog System with Surface Digitizing and MS DOS Compatible PC Versalogger System which includes the EDC-1C Depth Counter Module. There are accompanying drawings of the Light Weight Hoist Unit and a computerized well log system. In other words, Comprobe is a potential system manufacturer. Probes and accessories are listed in the Comprobe catalogue and prices were supplied separately.

Comprobe Inc. compares downhole telemetry versus surface digitizing methods. Telemetry is defined as the simultaneous processing of multiple downhole sensor signals and the communication with a surface modem which also obtains depth information from the cable sensor, ie: this is what we refer to as a digital system, with digital probes. The surface digitizing system uses analog (analog pulse) probes and has a surface or electronic module with analog to digital conversion unit.

The Comprobe manual describes a data acquisition system which acquires data from F.S.K. microprocessor based well logging probes with multi-receiver acoustics. A diagram shows the F.S.K. 8 bit bi-directional data packet logging probe detail and from the probe serial numbers on this diagram the probe O.D.'s appear to be 1 5/8" (41.3 mm) which exceeds our specified probe O.D. It is not known at this stage whether telemetered probes are available with O.D.'s of 1.3 inches (33 mm) or less as given in our design constraints. For this reason, we have only included the Comprobe analogue probes and accessories in our solution alternatives (Table 3).

2. Neltronic International Corp., Houston, Texas

Probe descriptions (Table 3) and prices were supplied by Neltronic International Corp. Note that the probe outside diameters exceed the specified 1.3 inch (33 mm) by 0.075 inch (2 mm). Probe power requirements are approximately 30 VDC at 30 ma. These probes are analogue in type and may all be considered as solution alternatives (Table 3).

3. Roke Oil Enterprises Ltd., Calgary, Alberta

Roke, in response to the design constraints for the geophysical probes, has supplied a treatise on slimhole logging which includes an overview, methods of measurements and procedures, a section on Roke Oil Enterprises Ltd., future development of logging equipment, comments on a mine logging system, logistics of marketing and operating logging equipment, applications and reservoir logging. Unfortunately there is no succinct description of the probes Roke proposes to supply for the In Mine Logging System.

TABLE 3
GAMMA RAY PROBE

	COMPROBE	NELTRONIC
Model #	1204LT	GM
Outside Diameter	1.25 inch (31.75 mm)	1.375 inch (34.93 mm)
Length	36 inches (914.4 mm)	50 inches (1270 mm)
Weight	8 lbs (3.632 kg)	11 lbs (4.994 kg)
Pressure Rating	5000 PSI (34500 kPA)	4500 PSI (31050 kPA)
Temperature Rating	120°F (48.9°C)	200°F (95°C)
Power at Probe	+ 120 VDC @ 60 ma, negative pulse	≈ 30 VDC @ 30 ma
Signal	Pulse Type	Pulse Type
Electronics		Solid Sate on Printed Circuit Board
Detector Type	NaI(Tl)	NaI(Tl)
Detector Dimensions	1/2 x 2 1/2 inch (12.7 x 63.5 mm)	0.75 x 4 inch (19.05 x 101.6 mm)
Crystal Efficiency	Not Available	Not Available
Photomultiplier	Yes	Yes
Calibration Accuracy		± 1%
Probe Range	0 - 100,000 cps	Maximum 10,000 cps (full scale) Minimum 50 cps (per 25 mm)
Probe Dead Time	40 µsecs	Not Available
Pressure Housing	Stainless Steel	Stainless Steel
Joints	Threaded with Double 'o' rings	Threaded with Double 'o' rings
Inner Body	Black Anodized Aluminum encloses scintillometer. Stainless steel enclosure around electronic chassis.	
Maximum Operating Cable Length	40,000 feet (12, 192 m)	
Top Sub Connection	Gearhart 1 or 4 Connector	Gearhart 1 or 4 Connector

TABLE 3 (Continued)
GAMMA-GAMMA (DENSITY) PROBE

	COMPROBE	NELTRONIC
Model #	1803-4π	DM
Outside Diameter	1 5/8 inch (41.275 mm)	1 3/8 inch (34.9 mm)
Length	Approximately 66 inch (1676.4 mm)	56 inches (1422.4 mm)
Weight	Not Available	15 lbs (6.81 kg)
Pressure Rating	20,000 PSI (13800 kPA)	4500 PSI (31050 kPA)
Temperature Rating	300°F (149°C)	200°F (95°C)
Power at Probe	+ 120 VDC @ 60 ma	≈ 30 VDC @ 30 ma
Detector (Crystal) Type	NaI(Tl)	NaI(Tl)
Detector (Crystal) Size	1/2 x 2 1/2 inch (12.7 x 63.5 mm)	0.5 x 2 inch (12.7 x 50.8 mm)
Crystal Efficiency	Not Available	Not Available
Photomultiplier	Yes	Yes
Probe Dead Time	40 μsecs	Not Available
Detector Shielding	Not Available	Not Available
Source Type	150 millicurie C_s^{137}	125 millicurie C_s^{137}
Collimation	Not Collimated - Omnidirectional	Collimated
Decentralization	Centralized	Bowspring
Calibration	Secondary Calibration Cylinders	Calibrated (API)
Calibration Accuracy		± 1%
Range	0 - 2000 cps	Maximum 10,000 cps (full scale) Minimum 50 cps (per 25 mm)
Linear Response	Yes	
Signal Type	Pulse	Pulse
External Fittings	Stainless Steel	Stainless Steel
Internal Shielding/Focusing	Not Focused	
Source-Detector Spacing	17.75 inch (450.85 mm)	Minimum 4 inches (101.6 mm)
Vertical Resolution	17.75 inch (450.85 mm)	Maximum 4 inches (101.6 mm)
Horizontal Field of Investigation	8.875 inch (225.425 mm)	Minimum 2 inch (50.8 mm)
Sub Top Connection	Gearhart Type (1 or 4)	Gearhart Type (1 or 4)
Maximum Operating Cable Length	40,000 feet (12,192 m)	Not Available
Electronics		All Solid Sate on Printed Circuit Board

TABLE 3 (Continued
NEUTRON-NEUTRON PROBE

	COMPROBE	NELTRONIC
Model #	1205	NM
Outside Diameter	1.25 inch (31.75 mm)	1 3/8 inch (34.9 mm)
Length	48 inches (1219.2 mm)	56 inches (1422.4 mm)
Weight	10 lbs (4.54 kg)	13 lbs (5.9 kg)
Pressure Rating	5000 PSI (34500 kPA)	4500 PSI (31050 kPA)
Temperature Rating	300°F (149°C)	200°F (95°C)
Power at Probe	+ 120 VDC @ 60 ma, positive pulse	≈ 30 VDC @ 30 ma
Detector Type	He^3 Proportional	Li^{6}I(Eu) Crystal
Detector Size	Not Applicable	3/4 inch x 2 inches (19.05 x 50.8 mm)
Photomultiplier	No	Yes
Probe Dead Time	40 µsecs	Not Available
Top Sub Connector	1 or 4 Gearhart Type	1 or 4 Gearhart Type
Maximum Cable Length	40,000 feet (12,192 m)	Not Available
Source Type	Am^{241} Be (1.2, 3.5 or 5 curie)	Am^{241}Be (3 curie)
Source-Detector Spacing	16 inch (406.4 mm)	Not Given in Specs
Vertical Resolution	16 inch (406.4 mm)	Not Given in Specs
Horizontal Field of Investigation	8 inch (203.2 mm)	Not Given in Specs
Collimated	No	No - Omnidirectional
Decentralization	Bowspring	No - Omnidirectional
Calibration		
Range		Maximum 10,000 cps (full scale) Minimum 50 cps (per 25 mm)
Calibration Accuracy		± 1%
Electronics		All Solid State on Printed Circuit Board
External Fittings	Stainless Steel	

In his Mine Logging System section, Roke proposes that the requirements be fully established for the probes (eg: qualitative or quantitative) and a feasibility study completed. For the conceptual design in this report, in which the main factors controlling the probe selection are that the probes measure coal seam depth and thickness and that their outside diameters are such that they may log inside BQ drill rods, it would appear that analogue probes are adequate. These have been constructed by Roke.

Roke's 43 mm (1.7 inch) O.D. probes are too large for BQ drill rods. His 32 mm (1.26 inch) O.D. probes are acceptable except that his Comprehensive Scientific Theoretical Model (CSTM) multifunction probe, including Quad Neutron, appears to be too long at 2.5 metres (8.2 feet) for use in a coal mine tunnel. Therefore, Roke probe specifications are listed in Table 2 as obtained from an older Roke catalogue and are not included in Table 3. Further investigation of Roke probes and their availability and specifications is required if it is considered advantageous to have a Canadian probe manufacturer.

3.5.1.4.2 Probe Selection

Selection of probes for the Conceptual Design is carried out using specifications as supplied by Comprobe Inc. and Neltronic Instrument Corp. as listed in Table 3. For the gamma ray probe, the Comprobe is considered to be the optimum choice in that it has smaller outside diameter, is lighter and shorter in length. Also, its NaI(Tl) crystal is smaller (1/2 x 2 1/2 inches or 12.7 x 63.5 mm) which may provide improved resolution assuming counting characteristics are the same. The manufacturer has confirmed that the + 120 VDC @ 60 ma, typ. negative pulse required for the gamma ray probe may be reduced to 115 VDC @ 50 ma which complies with the requirements for an intrinsically safe probe.

The gamma-gamma (density) probe selection is more complex in that Comprobe manufacture a number of these probes, none of which is satisfactory for our requirements. The Comprobe 1.25 inch O.D. High Resolution probe (# 1203) has a 50 millicurie Am^{241} source which is for use only in open holes (ie: cannot be used inside drill rods). The dual spaced (single source, two detectors) probes are too heavy, too long and have large O.D.'s (eg: 1 5/8, 2 1/8 and 2 1/2 inches or 41.275, 53.975 and 63.5 mm for models # 1852, 2152 and 2552 respectively). The

Comprobe 4π Omni Directional density Probe (# 1803-4II) as listed in Table 3 is an omnidirectional probe (ie: it is not collimated) with a large source-detector spacing (17.75 inches or 450.85 mm) and, hence, low resolution. Therefore, we would select the Neltronic gamma-gamma (density) DM collimated probe with a good vertical resolution of 4 inches (101.6 mm) with the smallest source-detector spacer available for this probe. The O.D. for this Neltronic probe is satisfactory at 1 3/8 inch (34.9 mm).

For the neutron-neutron probe we would again select the Comprobe Model 1205 in that it is shorter and lighter than the equivalent Neltronic Probe and has a smaller O.D. (1.25 inch or 31.75 mm). It seems that collimated slimhole neutron-neutron probes are not manufactured due to the major problems associated with shielding/collimating neutron source and detectors in such a small probe volume. Both Comprobe and Neltronic neutron-neutron probes are omnidirectional with relatively large source-detector spacing (eg: 16 inches or 406.4 mm) which gives relatively low resolution but samples a large volume of rock.

3.5.1.4.3 Explosion Proof, Intrinsically Safe or "Special Protection" Certified Probes.

None of the probe manufacturers will guarantee that their probes are explosion proof, intrinsically safe or "special protection" certified. However, since these slimhole probes are all designed to be pressure resistant and are sealed, it is considered that all types of probes will qualify as being explosion proof if the screw threads are acceptable. The external shell of the probes is constructed of stainless steel. Joints have a minimum of five threads together with a double 'o' ring seal. Hence, it is probable that the joints will be acceptable for the explosion proofing requirements.

With regard to the electronics, modern probes have solid state circuitry on printed circuit boards. An example of the circuitry for a gamma ray or gamma-gamma (density) probe is shown in Figure 3.5.1.4.3. This schematic indicates that the electronics, including the photomultiplier tube, should meet the intrinsically safe requirements or, alternatively, certified under the "special protection" category.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
-	-	PRELIMINARY ISSUE	-	

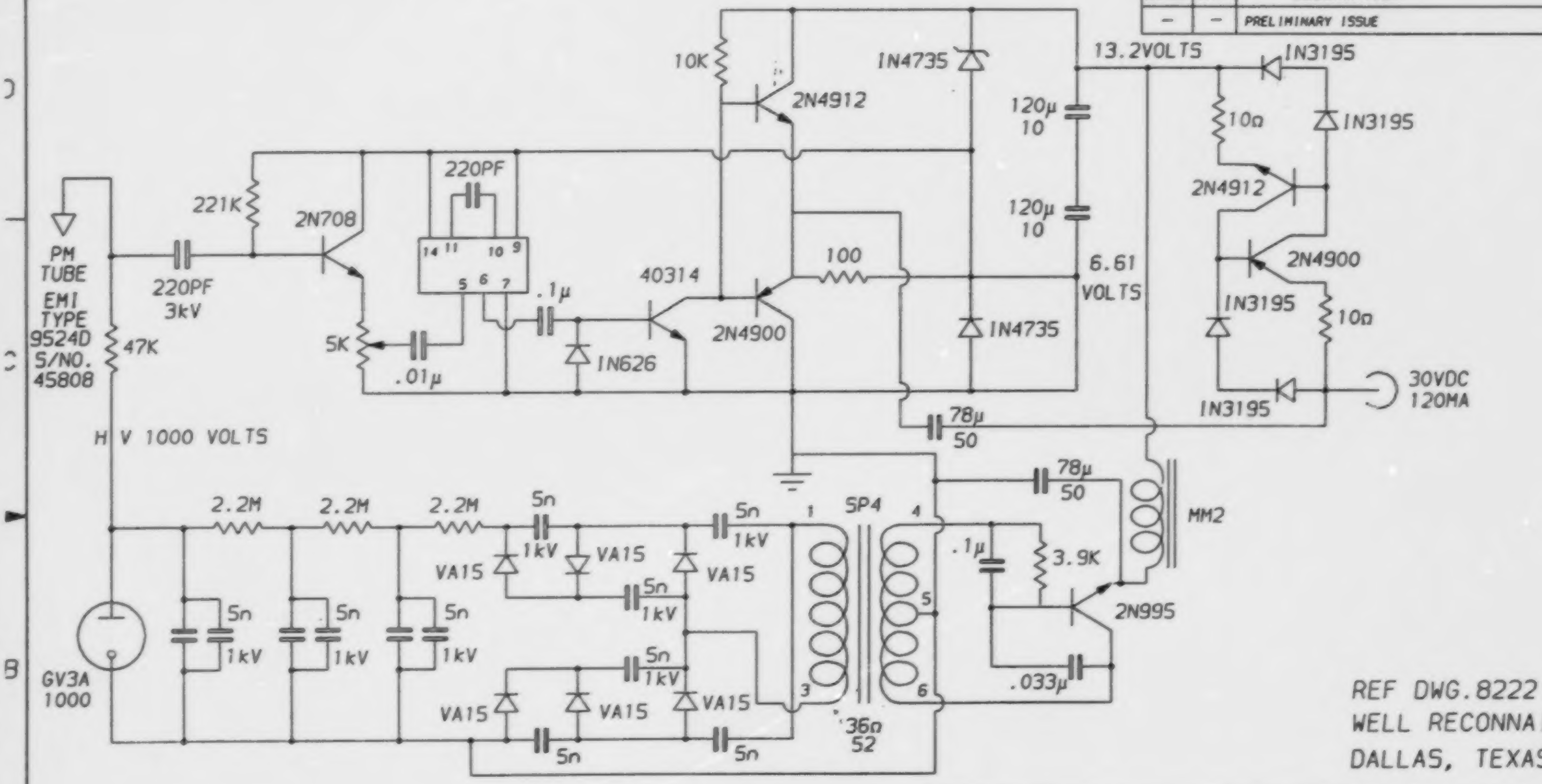

10K
2N4912
IN4735
120µ
10
120µ
10
13.2VOLTS
IN3195
10Ω
IN3195
2N4912
2N4900
IN3195
10Ω
IN3195
30VDC
120MA
PM
TUBE
EMI
TYPE
9524D
S/NO.
45808
221K
2N708
220PF
14 11 10 9
5 6 7
220PF
3kV
47K
5K
.01µ
.1µ
IN626
40314
2N4900
100
6.61
VOLTS
IN4735
78µ
50
H V 1000 VOLTS
2.2M
2.2M
2.2M
5n
1kV
VA15
SP4
1
3
4
5
6
36Ω
52
78µ
50
MM2
.1µ
3.9K
2N995
.033µ
GV3A
1000

Figure 3.5.1.4.3

REF DWG.8222 (5-11-70)
WELL RECONNAISSANCE INC
DALLAS, TEXAS

DO NOT SCALE

-	-
NEXT ASSY	USED ON

APPLICATION

MATERIAL
-
-

FINISH
-
-

UNLESS OTHERWISE NOTED
1. DIMENSIONS IN INCHES
2. 3 DEC PLACES ± .005
3. 2 DEC PLACES ± .010
4. FRACTIONS ± 1/32
5. ANGLES ± 1/2 °
6. ECCENTRICITY .005 MAX
7. SURFACE ROUGHNESS .125/ MAX
8. REMOVE SHARP

CONTRACT OR PROJECT NO.
-

DRAWN N.MCFETERS

CHECKED JD

APPROVED NAME

DATE JAN 11 91

NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA

TITLE
GAMMA PROBE SCHEMATIC DIAGRAM

SIZE B

CODE IDENT NO.

DRAWING NO. SK-0936

Similarly, from the selected probes it can be seen that the probe power requirements (30 VDC A 30 ma for Neltronic and 115 VDC @ 50 ma for the Comprobe probes) are within the limits specified in the Intrinsically Safe Category.

The small space inside the probe could be filled with inert material if deemed necessary by the regulatory authorities.

3.5.1.5 Cable

A number of geophysical logging cables can meet the cable design criteria including single conductor types. However, it was decided to use four conductor cable since it provides greater strength and hence reliability and a lower electrical resistance (by using three of the conductors and the armour as the probe power circuit). It has been the experience of NSRFC that this cable has never had to be re-terminated over a ten year working life. This means that less cable needs to be purchased to allow for re-termination. The lower resistance is advantageous when using battery power which is the preferred power source for the instrumentation unit. The specification of the selected cable is in the conceptual design section following.

Further advantages of the four conductor cable also include the following:

- It is less liable to kink than a single conductor cable in the rugged underground environment.
- Cable stretch is negligible over 1000 feet for a four conductor cable compared to a single conductor cable.
- It allows for incorporation of multifunctional probes in future equipment upgrades and developments.

3.5.1.6 Winch

There are a number of logging winches on the market which meet most of the design criteria. However, none of them are explosion proof. The feasibility of a given winch as a solution depends on how closely it can match the performance criteria and the ease with which it can be converted to or built as an explosion-proof unit. The feasibility of meeting the explosion-proof criterium depends on the manufacturer's willingness or ability to supply an explosion proof unit or the cost of converting a standard one by the system builder.

The main components of the winch are:

- Frame assembly
- Drum assembly
- Drive assembly
- Cable handling assembly
- Controls
- Slip ring

The only special requirement for the frame and drum assemblies is that they not be made from aluminum or its alloys or other similar light metals. The winch manufacturers contacted either have winches like this or will build them. Another option may be to purchase an aluminum winch and replace the aluminum components with a suitable material.

The options for the drive system are electric or hydraulic. The best choice is hydraulic because it is intrinsically safe and therefore avoids an expensive and heavy explosion-proof motor and controller enclosure. It also avoids the requirement to tap into the mine's power system for winch power. This is a bonus since there is not necessarily any mine power grid in the tunnel being drilled and setting up a junction box at the nearest source and running an extension is inconvenient and expensive.

The cable handling system consists of a level wind and sheaves. Ideally, the sheaves should be set up to allow line entry to the winch from various directions. A winch manufactured by Comprobe has this feature.

The controls must consist of:

- A manual brake
- A motor control system
- A line-in limit control

The motor control must be one capable of moving the cable at constant speed regardless of line tension and cable lay diameter. This will require a feedback control system with input from a cable position/velocity sensor. One way to do this is to have a servovalve controlling the motor using input from the position/velocity sensor. The cable position sensor requires a slotted disc or equivalent mounted on a pulley and a pair of sensors with appropriate circuitry to indicate direction of motion. Usually an optical approach would be used and this would be practical provided the disc and sensors were sealed to keep out dust. Alternatively, a combination of a slotted disc made of soft magnetic material with magnets and hall sensor (to detect field variations) could be used. Devices such as this are called encoders and are commercially available. Such units are incorporated into the design of the winches examined for this project. The servovalve could also take input from a line tension sensor and stop the winch if the line tension exceeded a maximum allowable value. The Comprobe winch has a line tension sensor which could serve this purpose.

The slip ring must have at least three passes: signal, power and common. The slip ring will need certification under the "special protection" category since it is fed by an intrinsically-safe circuit from the electronics module.

3.5.1.7 Active Probe Insertion (Uphole Logging)

For the purposes of this report uphole logging is defined as logging in holes which are horizontal or at any angle above the horizontal. There are a number of ways of inserting the probe into such holes. These include the following, with variations:

3.5.1.7.1
- Push the probe into the hole using a stiff member.
- Pull the probe into the hole using a cable over a pulley anchored at the hole end.
- Pump the probe into the hole using fluid pressure.

A number of companies and individuals we have contacted have had experience with the first solution and they inform us that it is practical for short holes (up to 300 ft; 91 m).

3.5.1.7.2 The second solution is incorporated into a logging system of a German manufacturer. This system requires two winches and appears to be for larger holes than those under consideration here. The German probe diameter is 60 mm (2.36"). In this solution, there is always the danger of the up and down cables getting tangled and this increases with increasing hole lengths and decreasing hole diameters. The advantage of this method though, is that it appears to be useable for open holes, although this is not a requirement on this project.

3.5.1.7.3 The third solution is one commonly used for retrieving core barrels in core drilling operations. It is also the subject of a number of patents (see "Patents" section). A version of this solution has been used by the Hudson's Bay Mining and Smelting Company for logging horizontal and above horizontal holes. With this track record of field use, it is felt that this is the most suitable solution for this project. However, we have not found any equipment manufacturer, survey company or end user who has logged vertically upwards with this system. The maximum angle above the horizontal for which logging has been carried out is 15 - 20° from our investigations to date.

3.5.1.8 Electronics Module

The hardware solution for the electronics module involves two of the areas mentioned at the beginning of this section, i.e. performance of standard logging functions and explosion proofing.

The following decisions were made incorporating the considerations for these two areas:

3.5.1.8.1 Explosion Proofing, Intrinsically-Safe Design, and "Special Protection" Certification

Since explosion-proof enclosures tend to be heavy and bulky, it was decided to use intrinsically-safe design to help meet the weight and portability criteria. In parts of the design, some features may qualify for "special protection" certification.

Intrinsic safety calls for techniques which avoid the risk of electrical discharges or hot areas able to explode methane or coal dust. Currents and voltages must be limited and capacitors and inductors restricted within safe limits. The curves reproduced in Bossert and Hurst (1986) define these limits in a practical way. Up to two failures in critical components (except those classified as inherently safe) must not cause a dangerous situation by causing these limits to be exceeded.

In some places, such as the battery enclosure, certification as "special protection" rather than intrinsic safety may be most appropriate.

3.5.1.8.2 Power Supply

Battery power is an attractive alternative to external power since it lends itself to intrinsically safe design or "special protection" certification and it eliminates the need to connect into the mine's electrical system with explosion - proof equipment means. It also reduces or eliminates the harmful effects of electrical transients and interference from the mine electrical system. Rechargeable batteries are preferable since they eliminate the battery replacement cost and eliminate the need for opening the battery containment. Batteries mean more weight, but the net additional weight is not much more than the weight of a power transformer which would be needed in the case of an external power supply.

The battery must be enclosed in a close-fitting box which will not be ruptured by a specified drop test. Protective devices will be included to preclude any dangerous fault condition.

Two reasonable candidates for battery choice are lead-acid gel cells and ni-cads. Of these, ni-cads have the advantages of being less susceptible to deterioration if left discharged. However they are expensive in larger sizes so we prefer the lead-acid gel-cell which is made by a number of companies.

3.5.1.8.3 Data Storage Processor, Display and Input

To achieve portability, ruggedness and an intrinsically safe design, the traditional chart recorder will not be included in the system. (However, an analog output will be provided for when an external chart recorder may be used.) Instead, data will be stored in electronic media for portability, ruggedness and intrinsically safe design. Hard or floppy discs will not be used. Data will be stored in CMOS static random access memory (SRAM).

For an "on the job" display of the data, a liquid crystal or electroluminescent flat panel display would be practical and inexpensive. Liquid Crystal Display panels are now available from several makers in sizes up to 720 x 480 dot pixels (Optrex). Also available are electroluminescent panels. A panel such as 512 x 256 should be adequate to show the required three side by side plots of the gamma ray, gamma-gamma (density) and neutron-neutron logs. It would be purchased with electronics for interfacing and control and a matching inverter. Viewing area for the module would be of the order of 125 x 100 mm. The LCD panel would need to be back illuminated with LEDs. The analog display of data the panel will also be used to show alphanumeric messages and prompts.

For the in-mine logger it may also be practical to utilise a laptop computer. There are many models to choose from and it is likely that one could be found which was sufficiently rugged and was, or could, easily be made to be, intrinsically safe. It would have to be able to interface with a data acquisition module and would have to have the needed amount of solid state memory. It would be fitted inside the electronics module and probably a touch pad type keyboard would be substituted for a key type.

Because so much of what would be needed would be built-in, a laptop would likely be the most cost effective solution for a first prototype and for a batch of six or less units. For a larger production run a computer board or module either specially designed, or selected in the marketplace with separately purchased display, keyboard and input and output modules would probably be preferred.

3.5.1.8.4 Data Output

An alternative could be the use of a specialized direct offload facility of which an example is Onset Computer Corporation's "Direct-6" which could transfer the full data load in parallel form in less than 1 minute into a PC-AT. This requires the PC to be fitted with a special plug-in card.

3.5.1.8.5 Probe Interface Digital Circuitry

This could be purchased modules matched to the particular tools selected. It might also include one or more specially constructed low power circuits since the functions performed are relatively simple and the cost of designing them should be small.

3.5.1.8.6 Software for the Logging System

The in mine logger software is to be developed using a high-level language such as C or Pascal. The use of assembly language is not recommended unless it is necessary to re-code specific modules when they are not fast enough. There are two main approaches applicable to this project, depending on the choice of field system/development system.

The first approach assumes the use of a stand-alone processor/data acquisition board (or boards). Program development is done on a separate PC using a suitable cross-compiler (eg: Archimedes "C"). The compiled program code file is transferred to a PROM programmer, and the PROM chips installed on the processor's memory board.

The second approach is to use a flameproof IBM-compatible PC laptop and a standard data acquisition board (eg: Tecmar LabMaster). With 'expanded' memory installed (3-4 MB), the program writes directly to a RAM disk drive emulator (eg: RAMDRIVE in MS-DOS). The program is compiled with a standard MS-DOS language (eg: Turbo Pascal, Turbo C).

In order to organize and isolate unique processing tasks the logger program will be made up of several modules. The following major modules can be identified at this stage in the design. Each major module can be made up of several minor modules.

3.5.1.8.7 Initialization

The initialization section performs essential processor diagnostics to ensure system integrity. Then the user menu is displayed, with an automatic entry into the Header Data Segment (section F. below) input screen if data logging has been requested.

In addition, calibration tests may be requested for the logging probes to ensure they are operating correctly. Total gamma ray probes are calibrated in API units (0 - 200), gamma-gamma (density) probes are calibrated in gm/cc, and neutron-neutron probes in porosity units %.

3.5.1.8.8 User Interface

This section controls processing of the user's menu requests through the control panel. It supervises the entry of user information, including the header and footer data. It also controls the display of all menus, header and footer data, sampled data graphs, and real-time warnings and error messages.

Some of the features of the interface are:

3.5.1.8.8.1 On-screen reminders when logging is stopped by either a user command or the winch stopping.

3.5.1.8.8.2 When the winch stops during a logging run, the data sample will be modified with an appropriate error flag.

On-screen warning message stating that winch has exceeded maximum logging speed for 0.5 cm sample intervals.

3.5.1.8.9 Data Acquisition

The winch operates in data logging mode with a normal top speed of 10 m/min, and with an elevation resolution of 0.5 cm. This means a maximum time sampling rate of 34 samp/s or 30 msec/samp. The program must acquire a 12-bit sample, convert it to 2-byte format, and save it in the correct memory location within 30 msec. The newly acquired data sample, and its corresponding elevation, are displayed graphically at the same time.

Within the 30 msec sampling window, this section checks the winch position counter, waits until the next 0.5 cm elevation increment, and acquires the corresponding count reading from the probe. The data sample is stored in the correct RAM location (section 3.5.1.9.11 below), and the process repeats. It is preferable to have the data acquisition modules triggered by an external hardware interrupt from the winch controller or the signal conditioning circuitry. This avoids using a scheduling algorithm and polling the data acquisition board within the correct time frame.

3.5.1.8.10 Data Display

This section produces a scrolled data chart on the display panel in real time as data is acquired. It also generates an elevation-only display in order to perform borehole elevation checks. The data scrolls can start at any elevation branch in the log.

Header and footer information can also be displayed at the user's request for any specified log. (See Figures 3.3 & 3.4)

At least 100 pixels should be used on the horizontal data axis for each of three side-by-side data scrolls. This requires a minimum of 300 pixels in the horizontal panel direction.

A smart panel should be used so that ASCII character codes can be used directly, rather than having the logger program convert from characters to pixel patterns. Pixel translation requires the preparation and storage of a large character set pixel table.

Vertical display units are meters or tenths of meters, and horizontal display units are counts per second and/or calibration units for the probe. The user can specify arbitrary scale factors for both display axes, although the program provides default values.

3.5.1.8.11 Data Storage

Each data log consists of three segments:

- Log header segment
- Sampled data segment
- End of log footer

3.5.1.8.11.1 The header segment (see Figure 3.3) contains the log name, location, borehole #, date, time, initial elevation offset, calibration data, etc. This section requires a few hundred bytes of RAM.

3.5.1.8.11.2 The sampled data segment (see Figure 3.5) contains two-byte packets for each sample. Each packet contains 12 bits of count data for the sampling interval. Each packet also contains control information in the high four bits for change in direction flags, critical hardware failure flags, etc. Elevation data is not stored, but is implied in the sample's memory address: each 2-byte increment in the address space corresponds to another 0.5 cm elevation increment. This segment needs about 128 kilobytes of RAM for each log, to a maximum of twenty logs per day.

3.5.1.8.11.3 When a log is complete, the user may request to see scrolled data displays, starting at any elevation along the log. However, since the logging direction can be reversed at any elevation during the log, multiple occurrences of the same elevation will be recorded in separate branches of the log.

In order to uniquely identify portions of the log which have identical elevations, the log is divided into branches, each identified by a branch header containing:

G, N, or D: 1 letter denoting the type of log
n: 1 digit denoting the branch number
U or D: 1 letter denoting the logging direction
ssss.s: a 5-digit starting elevation
eeee.e: a 5-digit ending elevation

The user selects a branch for data scrolling by specifying the first three branch header characters, eg: N6D denotes a neutron-neutron log, branch 6, descending.

The footer contains additional descriptive information about events during the log, a second set of calibration data, a second elevation offset, etc.

3.5.1.8.12 Data Transfer

To facilitate data analysis, it is necessary to transfer the data to a PC and store it in a format that is accessible to a variety of processing software (eg: Fortran, Lotus 123). This requires translation from binary format to ASCII-text format.

The data transfer section of the program must read RAM locations sequentially, send the data bytes to the PC via serial or parallel link, and allow time for the PC to store the binary data in a hard disk file.

This section transfers all of the data (headers, data samples, and footers) stored in RAM to an IBM-compatible PC. The data is transferred via serial link at 9600 baud, or by a parallel link at higher baud rates. A supplementary program must also be written or purchased for the PC so that it can capture the incoming data and store it in a hard disk file.

Converting from binary data to ASCII-text should be done by a utility program after the data transfer is complete. This avoids a time-consuming process interfering with data acquisition and data transfer, each of which have their own timing constraints.

Data transfer to floppy disks is not recommended. The expected volume of data makes it impractical to swap disks, especially if data transfer is done overnight at low baud rates. Data can be backed up to floppies after the transfer is complete, using MS-DOS Backup or a commercial backup program.

3.5.1.8.13 Postprocessing Unit

The post processing unit will be a standard PC 286 or 386 desk top or lap top model provided at the discretion of the user. It will require suitable output devices such as a 24 pin dot matrix printer and/or plotter. This unit is not part of the In Mine Logging System as described in this report.

3.5.1.8.14 Software - Postprocessing

Software for log presentation and interpretation needs to be acquired by the user for use on the PC. This software is not part of the In Mine Logging System as described in this report.

4 CONCEPTUAL DESIGN

This section of the report addresses the seventh step in the conceptual design phase as outlined in Figure 3.1: communicate the design solution. Basically, it is as complete a description as possible of the output of design Phase One, i.e., The Design Concept.

4.1 Overview

Drawing D-SK-0890 (see back pocket) gives an overall view of the in-mine borehole logging system. It consists of nine items which will be described individually in this section. In general, the system consists of the usual borehole logging components: probe, cable, winch and electronics module to which have been added other components to enable active probe insertion. Also, all components are explosion proof or intrinsically safe to mine standards.

4.2 Geophysical Probes

The three probes required for this system are:

- Total or natural gamma ray probe
- Gamma-gamma (density) probe
- Neutron-thermal neutron probe

The manufacturer's specifications for each of these probes follows.

The following probes and accessories are designated for the Conceptual Design:

1. Gamma Ray Probe: Comprobe 1240LT 1 1/4 inch (31.75 mm) probe

2. Gamma-Gamma (Density) Probe: Neltronic DM 1 3/8 inch (34.925 mm) collimated density probe

3. Neutron-Neutron Probe: Comprobe 1205 1 1/4 inch (31.75 mm) probe

4. Accessories:

    1. Neutron Source 3 curie Am^{241} Be Comprobe # 9380-000
    2. Density Source 125 mullicurie C_s^{137} Neltronic specifications
    3. Neutron Storage Shield Assembly Comprobe # 4000-002
    4. Density Storage Shield Assembly Neltronic specifications
    5. Density Calibrator, Aluminum Comprobe 4PI SPECIAL
    6. Density Calibrator, Magnesium Comprobe Specification
    7. Density Calibrator, Acrylic Comprobe 400-021

    } May require Neltronic equivalent

8. Neutron Acrylic Cube-Type Calibrator: Comprobe 4000-02b

9. Neutron Source Holder Comprobe 4000-015

10. Density Source Holder Neltronic specification

11. Manuals for above probes including electronic schematics, probe assembly schematic, maintenance and repair descriptions

These probes shall be used singly on a given run to obtain the desired log. If the hole does not require active probe insertion such as for straight holes in a substantially downward direction, then the probe assembly shall consist simply of the probe and cable head. For holes requiring active probe insertion, the probe assembly shall also include components for making a seal against the inside wall of the drill pipe as shown on drawings B-SK-0897 and B-SK-0900 (see back pocket). The sealing components shall consist of housings having annular grooves for accepting elastomer seal rings. The housings will be built to fit the three probes and will allow decentralization of the probe where necessary. The housings will also be designed for quick assembly and disassembly without disconnecting the probe from the cable to provide for efficient and safe changes from one log type to another and from one hole to another.

4.3 Geophysical Cable

The recommended cable is an industry standard for borehole logging use. It has adequate strength and resistance to kinking with acceptable weight and satisfactory electrical qualities. For construction details, refer to Figure 4.3. The following data for this cable type is taken from the catalogue of the Rochester Corporation, P.O. Box 312, Culpeper, Virginia, USA 22701. (Telephone (703) 825 2111).

Type: Multiconductor armoured cable, four conductor double armoured. Type 4-H-185.

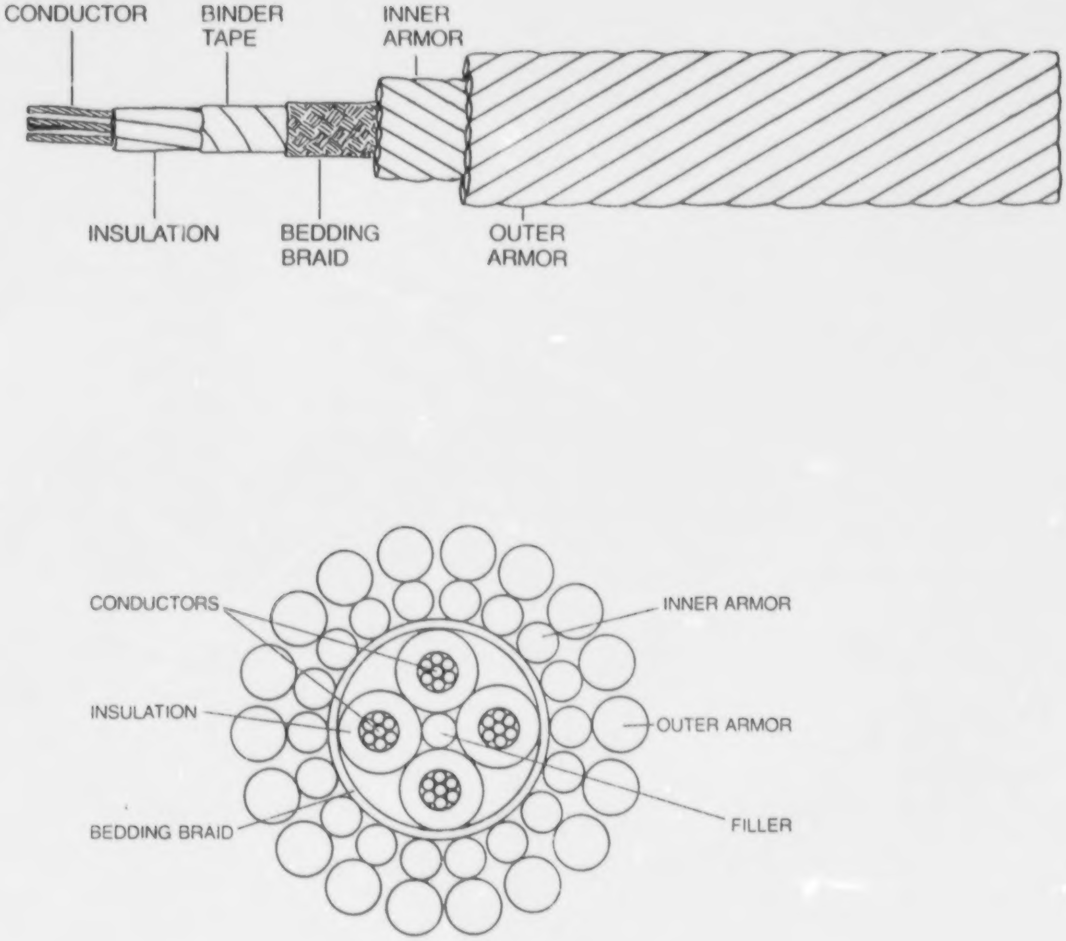
Specification		
Diameter	0.183 in	4.65 mm
Weight	57 lbs/1000 ft	28 Kg/ 335 m
Minimum sheave dia.	10 in	250 mm
Breaking strain	2900 lbs	1300 Kg
Conductor resistance	26 ohms/1000 ft	29 ohms/335 m
Conductor capacitance	59 pF/ft	65 nF/335 m
Conductor inductance*	(calculated)	120 uH/335 m
L/R ratio	(calculated)	4.2 uH/ohm

Note inductance has been calculated using the formula in Terman p52 (see reference) for concentric conductors.

$L = 0.46 \log r2/r1 + 0.049$ uH/m.
with $r1 = 0.5$ mm, $r2 = 2.5$ mm

The presence of the three other conductors was ignored; hence inductance will be slightly less than that calculated.

Figure 4.3


CONDUCTOR
BINDER TAPE
INNER ARMOR
INSULATION
BEDDING BRAID
OUTER ARMOR
CONDUCTORS
INNER ARMOR
INSULATION
OUTER ARMOR
BEDDING BRAID
FILLER

Typical Construction of a Multiconductor Armored Cable

The L/R ratio has been calculated because if it exceeded 25, cable inductance would have to be taken into account in assessing intrinsic safety. Clearly, it is not of concern. Cable capacitance is also not of concern according to the chart of Bossert (Figure 11-17 - see Reference) since voltage will be far below the 300 volts allowed for this value.

4.4 Winch

The winch shall be the light-weight hoist shown on Comprobe Inc. Dwg. 5020-508 (Figure 4.4-1) except with a hydraulic drive. It shall include a Comprobe electronic depth indicator # EDC-1C (Figure 4.4-2) shown on Dwg. 9000-022 and a line tension sensor. The hydraulic drive system shall incorporate a manual directional control valve and a manual flow control valve which produces a constant drum speed. Also included is a local line tension output and over-tension protection. The winch shall also have a slip ring which will pass the intrinsically-safe probe power and signals. The hydraulic system will also incorporate a stop valve activated by a trip on the cable.

Hydraulic power will be supplied by either the drill's power pack or a separately supplied one if the drill is not present. Electric power for these units will be supplied from the mine's system. See Dwg. C-SK-0902 (back pocket).

4.5 Water Sub-System

As well as hoses the water sub-system comprises a Seal Tee Assembly, the water pump and a water control manifold.

4.5.1 Seal Tee Assembly

This component provides a means to allow pumping water into the drill pipe behind the probe assembly. It is a modified version of an item of the same name made by the Longyear Company. Figure 4.5.1 is an exploded view of this assembly. it shall be made in such a way that it can be removed from the cable without disconnecting the probe.

4.5.2 Water Pump

This pump must provide the water flow and pressure to pump the probe up the hole. A candidate pump for this task is the water pump used for the drilling operation. Such pumps are already used for pumping "overshots" up the inside of the drill pipe to retrieve core barrels. A suggested unit is Longyear's 535H hydraulic pressure pump. If the drill is still at the hole, the pump will automatically be available; if it is not, one will have to be provided with the logging system. The following table shows the resulting probe speeds that can be obtained with this pump assuming full flow to the seal tee and no "blow-by" past the probe assembly.

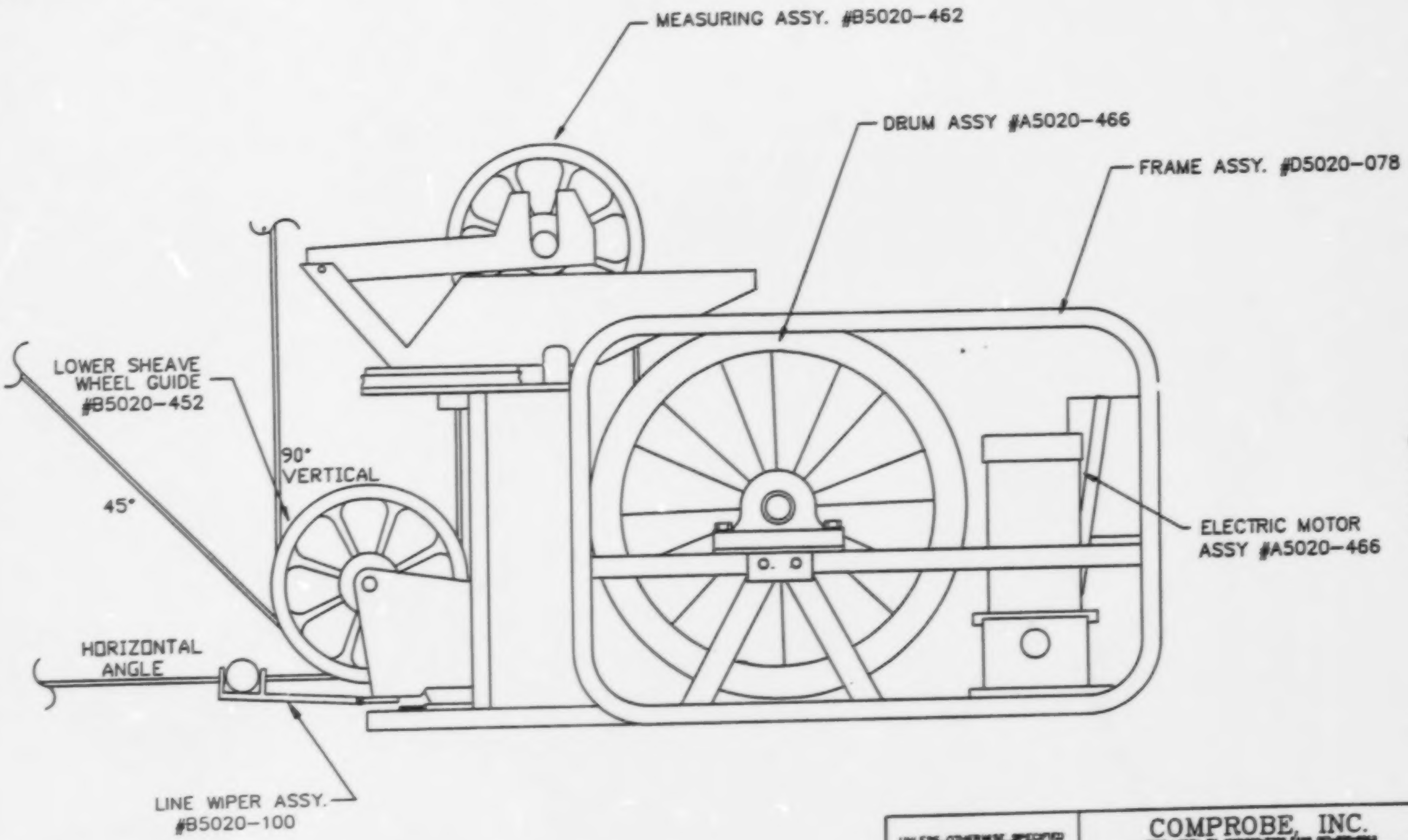

MEASURING ASSY. #B5020-462
DRUM ASSY #A5020-466
FRAME ASSY. #D5020-078
LOWER SHEAVE WHEEL GUIDE #B5020-452
90° VERTICAL
45°
ELECTRIC MOTOR ASSY #A5020-466
HORIZONTAL ANGLE
LINE WIPER ASSY. #B5020-100

Figure 4.4-1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

COMPROBE, INC.

TITLE LIGHT WEIGHT HOIST
UNIT #500-3001
TOP DWG

NEXT ASSY. USED ON

PREPARED 12-05-90

DRAWING # 5020-508

DO NOT SCALE DRAWING

SCALE N/A

THIS DRAWING AND SPECIFICATIONS HEREIN ARE THE PROPERTY OF COMPROBE INC. AND SHALL NOT BE REPRODUCED OR COPIED OR USED IN WHOLE OR IN PART AS THE BASIS FOR MANUFACTURE OR SALE OF ITEMS WITHOUT WRITTEN PERMISSION FROM COMPROBE INC.

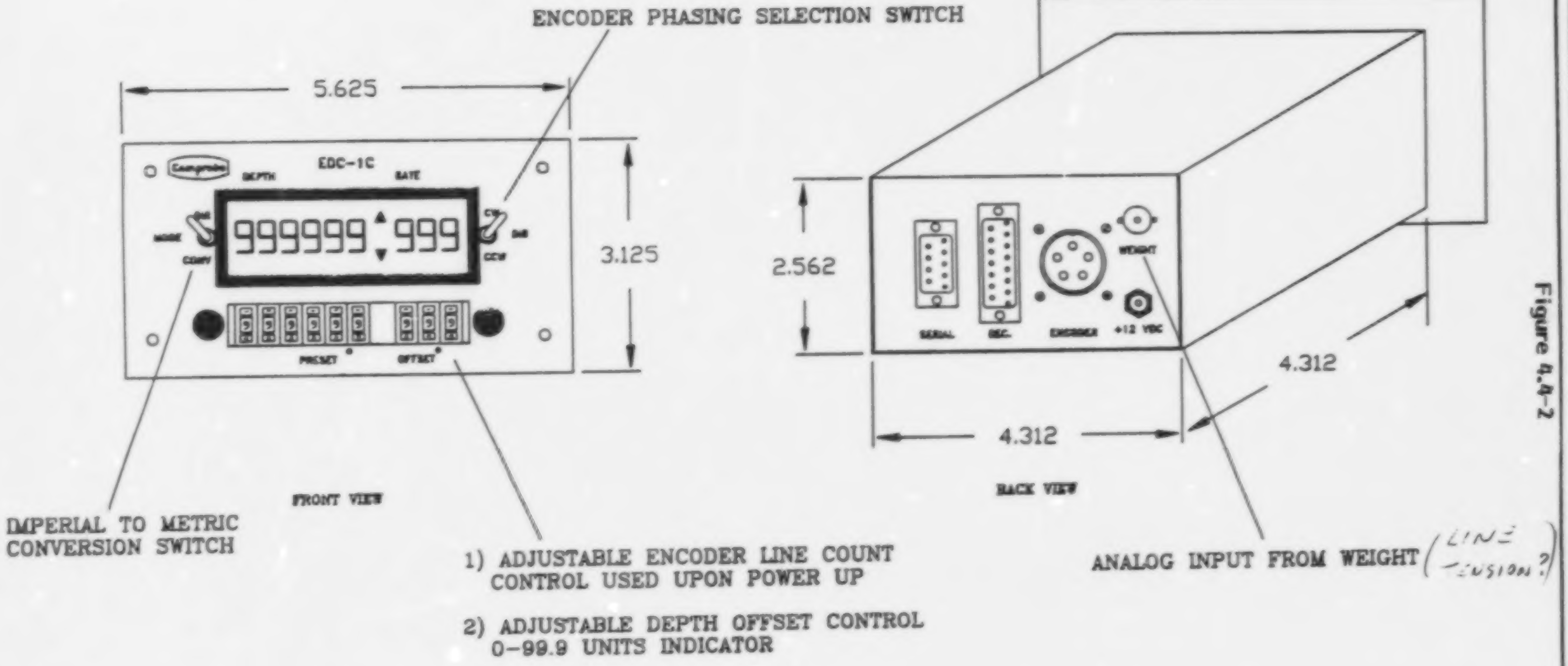

ENCODER PHASING SELECTION SWITCH
5.625
3.125
EDC-1C
DEPTH
RATE
999999
999
MODE
CONV
CW
CCW
PRESET
OFFSET
FRONT VIEW
IMPERIAL TO METRIC CONVERSION SWITCH
1) ADJUSTABLE ENCODER LINE COUNT CONTROL USED UPON POWER UP
2) ADJUSTABLE DEPTH OFFSET CONTROL 0-99.9 UNITS INDICATOR
2.562
SERIAL
SEC.
ENCODER
WEIGHT
+12 VDC
4.312
4.312
BACK VIEW
ANALOG INPUT FROM WEIGHT (LINE TENSION?)

Figure 4.4-2

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMALS
ANGLES 1/2
FRACTIONS 1/20

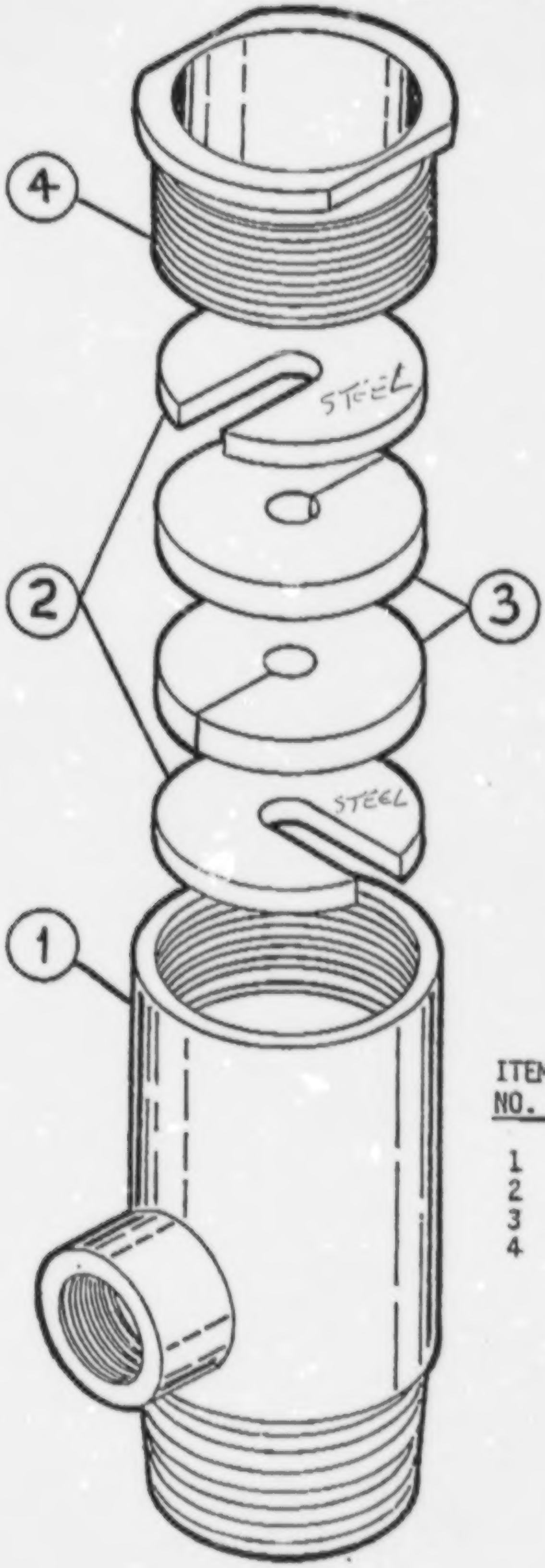
9000-021 | EDC-1C ASSY
NEXT ASSY. | USED ON
PREPARED 8-30-90
CHECKED
APPROVED

COMPROBE, INC.
FORT WORTH, TX

TITLE
ELECTRONIC DEPTH INDICATOR
EDC-1C

SIZE A
DRAWING # 9000-022
MATERIAL
FINISH
DO NOT SCALE DRAWING
SCALE 1/2
SHT OF

Figure 4.5.1


4
STEEL
2
3
STEEL
1

SEAL TEE ASSEMBLY

ITEM NO.	PART NO.	QTY REQD	DESCRIPTION
1		1	Body
2		2	Washer
3		2	Seal - Rubber
4		1	Cap - Compression

Table 4.1

Longyear 535H Probe Speed Capability

Flow (USGPM)	DRILL ROD			PROBE SPEED	
(USGPM)	Size	I.D. (IN.)	Volume (USG/100FT.)	(FT/MIN)	(M/MIN)
35	BQ	1-13/16	13.4	261.2	79.6
	NQ	2-3/8	23.0	152.2	46.4
	HQ	3-1/16	38.2	91.6	27.9

Maximum required logging speed is 10 m/min so this pump is adequate for all drill pipe sizes. Maximum pay-out and retrieve speed is 45 m/min, so this pump is adequate for all but the HQ drill pipe size. Here slower speed will have to be tolerated.

Hydraulic power for the water pump will be supplied by either the drill's power pack or a separately supplied one if the drill is not present. Electric power for these units will be supplied from the mine's system. See Dwg. C-SK-0902 (back pocket).

4.5.3 Water Control Manifold

The purpose of this assembly is to control the pressure and flow of water to the seal tee to get the desired probe speed. It will consist of a piping arrangement as shown on Dwg. C-SK-0890 enclosed in a small enclosure with a panel front. The panel front will have a piping circuit schematic marked on it with the control knobs protruding through at appropriate points. The panel will be light and portable and will have a hanger arrangement for hanging it in a convenient location near the pump or seal tee. The operator will be able to monitor nominal line speed by observing one of the flow meters on the panel and will be able to make flow and pressure adjustments as necessary using the valves.

4.6 Electronics

4.6.1 Design Aspects

4.6.1.1 General

As for the entire geophysical in-mine logging system, the electronics module must be designed so that is cannot initiate an underground explosion if it is to be approved for use in a coal mine. To this end, the module will be designed to be intrinsically safe with, perhaps, some features qualifying for "special protection" certification. Its construction will avoid aluminum and like metals able to produce dangerous sparks when struck by rusty steel.

Also important is portability, hence the specified weight limit of 50 Kg must not be exceeded.

To achieve portability, ruggedness and intrinsic safety, data will be stored in integrated circuit memory and read out into a personal computer at the end of a day's work. Appropriate software can then be used to process and present the recorded information as required. For an "on the job" display to confirm that the equipment is operating properly, either a liquid crystal, or electroluminescent flat panel, display would be practical and inexpensive. However, to accommodate a user wishing to obtain an immediate hard copy, a connector will be provided for an external explosion proof chart recorder.

In reviewing the borehole logger marketplace, it was apparent that several makers of modern surface operated loggers are currently adopting a quite similar approach to that proposed in the report but with the data storage, processing and display functions performed by an external standard laptop computer.

One potentially beneficial result of this trend is that software has already been written which is quite similar to that required for this project and may be adaptable for some, at least, parts of this project.

As pointed out in section 3.5 "Solution Alternatives," it may be practical to utilise a laptop computer for this job. There are many to choose from and it is likely that one could be found which was sufficiently rugged and was, or could easily be made to be, intrinsically safe. It would have to be able to interface with a data acquisition module and with the needed amount of solid state memory. It would be fitted **inside** the electronics module and probably a touch-pad type keyboard would be substituted for a key type. Because so much of what would be needed would be built-in, a laptop could likely be the most cost-effective solution for a first prototype and for a batch of six or less units. For a larger production run a computer board or module either specially designed, or selected in the marketplace with separately purchased display, keyboard and input and output modules would be more cost effective.

4.6.1.2 An Intrinsically-Safe Electronics Module

Intrinsic safety of the electronics module calls for techniques which avoid the risk of electrical discharges or hot areas able to explode methane or coal dust. Currents and voltages must be limited and capacitors and inductors restricted within safe limits. The curves reproduced in Bossert and Hurst (1986) define these limits in a practical way. Normal operation, or up to two failures in critical components (except those classified as inherently safe), must not cause a dangerous situation by exceeding these limits.

As discussed above (3.5.1.9.2), a rechargeable lead-acid battery is the preferred power source for this module. The battery will be enclosed in a close fitting box which will not be ruptured by the drop test specified for the electronics module. To guard against charging mishaps, pressure relief valves in the box and also in the unit's case may be needed to discharge gas (charging will only be done in a gas-free area). The battery box should also not corrode if it comes into contact with the acid gel normally sealed in the battery of which the corrosive part is sulphuric acid.

The battery's external connections will need to be correctly designed. For the charging input two diodes in series - which could be part of the charging circuit's bridge rectifier, plus a transformer and fuse will provide ample protection bearing in mind that charger power will never be present underground.

Inside the box, one or more current-limiting resistors of non-fault-subject metal film construction must be installed to restrict the worst-case current from the battery. One resistor-protected output from the battery will power the electronics. A DC to DC power supply will convert the 12 volts from the battery to the voltages needed by the electronics. If a laptop computer is incorporated, this power supply will be built into it. There will be a second protected output from the battery for a DC to DC converter which will provide tool power.

If one or more Comprobe tools are included these will require 115 V at approximately 50 mA. The nominal rating is 120 V at 60 mA but we were informed that this could be reduced especially in view of the short cable which would be used. This is the highest voltage of all probe types but according to curves in Figures 11.15, 11.16 and 11.17 of Bossert and Hurst would be acceptable. The appropriate curves are those for IEC Group 1 - apparatus. Even with aluminum present - which can almost certainly be avoided - the voltage and current are acceptable provided capacitance is kept below 0.1 μF which is not difficult.

As an alternative to being certified as "intrinsically safe," the battery and its protective components may be certified on the basis of "special protection."

4.6.2 Block Diagram Level Description

Figure 4.6.2-1 is the block diagram of the electronics. This is made up of two sub-systems: power and signals/data. The power source is the 12 volt battery. This is charged at the surface using the built-in battery charger. The battery charger is powered by 115 volt 60 Hz AC (i.e. ordinary line power) and consumes approximately 25 watts. The power from the battery is conditioned for the electronics by the DC to DC power supply. This supplies power for the electronics at the various voltages required and also provides intrinsic safety by appropriate limits on voltages and currents. A similar unit, the DC to DC converter, supplies the power required by the probe and also is designed to ensure intrinsic safety. The power supplied to the probe must take into account the voltage drop along the logging cable. To minimise the drop three conductors in parallel are used with the cable armour as the return path.

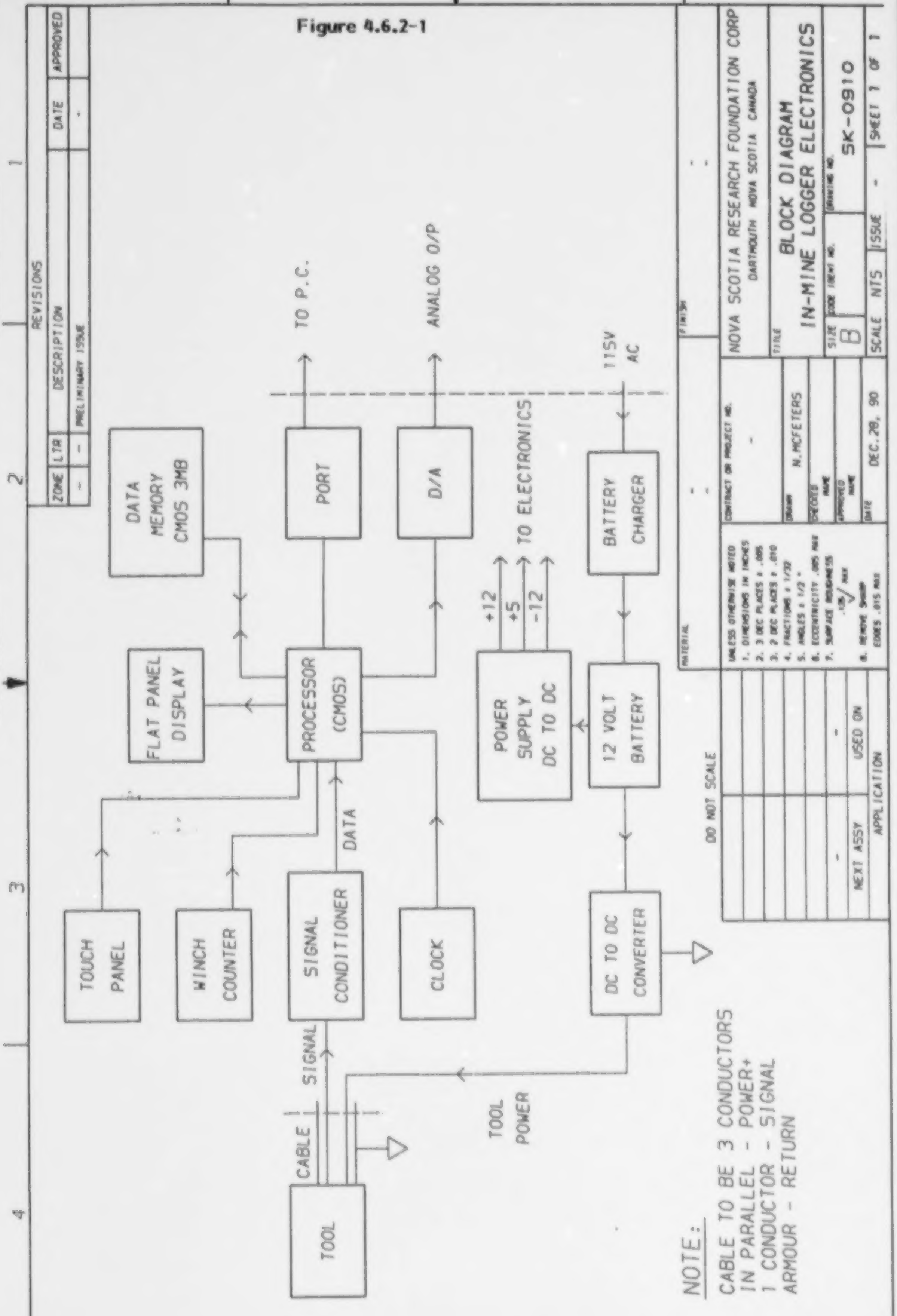
Built into the tool another DC/DC converter generates the low current high voltage supply to the photomultiplier tube. In the circuit of Figure 4.6.2-1 this is shown as 1000 volts. Current will range from 0 to 1 microamp.

The signal from the tool in use passes though one conductor of the logging cable to the Electronics Module. The return path for the tool signal is again the cable armour. If the tool is an analog type, the pulse signals from it will be re-formed by a signal conditioner and fed into a counter. At intervals the counter content will be latched into a register and read by the processor. The output from a digital tool will also need re-forming but then will pass directly to the processor.

Other inputs to the processor are: the digital output of a clock integrated circuit (IC), a number indicating cable position from a counter driven by the winch up/down pulse generator, and inputs from the contacts of the touch panel keyboard used for inputting commands and information.

The processor has four outputs by way of its data bus: a flat panel display which shows data in graphical form plus script messages; a data memory capable of storing three 8 bit megabytes of data (this output can also be used as an input to the processor from the memory): an analog output using an digital-to-analog converter; and a serial port to which a personal computer can be connected at the surface to transfer data into it from the memory via the processor. There will likely also be a fifth output in the form of a parallel port for rapid transfer of the data to the personal computer.

Figure 4.6.2-1


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
PRELIMINARY ISSUE
DATA MEMORY CMOS 3MB
FLAT PANEL DISPLAY
PROCESSOR (CMOS)
PORT
TO P.C.
D/A
ANALOG O/P
TOUCH PANEL
WINCH COUNTER
SIGNAL CONDITIONER
DATA
CLOCK
POWER SUPPLY DC TO DC
+12
+5
-12
TO ELECTRONICS
BATTERY CHARGER
115V AC
12 VOLT BATTERY
DC TO DC CONVERTER
TOOL
CABLE
SIGNAL
TOOL POWER
NOTE:
CABLE TO BE 3 CONDUCTORS
IN PARALLEL - POWER+
1 CONDUCTOR - SIGNAL
ARMOUR - RETURN
DO NOT SCALE
NEXT ASSY
USED ON
APPLICATION
MATERIAL
FINISH
UNLESS OTHERWISE NOTED
1. DIMENSIONS IN INCHES
2. 3 DEC PLACES ± .005
3. 2 DEC PLACES ± .010
4. FRACTIONS ± 1/32
5. ANGLES ± 1/2 °
6. ECCENTRICITY .005 MAX
7. SURFACE ROUGHNESS .125 MAX
8. REMOVE SHARP EDGES .015 MAX
CONTRACT OR PROJECT NO.
DRAWN N.MCFETERS
CHECKED NAME
APPROVED NAME
DATE DEC.28, 90
NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA
TITLE BLOCK DIAGRAM IN-MINE LOGGER ELECTRONICS
SIZE B
CODE IDENT NO.
DRAWING NO. SK-0910
SCALE NTS
ISSUE -
SHEET 1 OF 1
A
B
C
D
1
2
3
4

4.6.3 Detailed Description of the Electronics Module

4.6.3.1 Power Supply

An external power source will usually be available since the winch will require an AC supply. However an internal battery supply is proposed and as indicated above, a lead-acid gel-cell rechargeable battery will be used. This is to avoid the use of a clumsy cable and connectors and equally important to reduce the risk of disruptive electrical interference from the mine power system.

The battery load can be initially estimated as follows:

A liquid crystal display backlit using light emitting diodes (LEDs) requires approximately 100 mA at 12 volts. Alternatively, an electroluminescent display would typically use 0.5 to 1.0 A at 12 volts.

The cable-out counter on the winch will need 20 mA at 12 volts.

Signal-conditioning circuitry will use 50 mA at 12 volts.

The CMOS processor plus AD converter requires a maximum of 20 mA at 5 volts.

Three megabytes of 8-bit memory (see paragraph 4.6.3.2.2) using static MOS RAM will need 30 mA approximately standby. When storing data, the one 128k chip being loaded will consume an additional 50 mA.

Probe power requirements depend on the probe design selected. Five watts is average for probe power requirement. Different manufacturers 'probes require from + and - 5 volts to 115 V at 50 mA. A DC to DC power conversion module will be used to step up the battery voltage to the specified level. This is expected to be at least 60% efficient and consume 8 watts of battery power.

In summary, total estimated battery load is:

Display LCD	100 mA, (converted to +5 and -12 volts)
Cable Counter	20 mA
Signal conditioning	50 mA
AD and processor	20 mA (regulated down to 5 volts)
Memory maximum	80 mA (5 volts)
Probe	670 mA (= 8 watts at 12 volts)
Total	940 mA (using LCD display)

Total using EL display 1.4 to 1.9 A

As an example, a Dynasty 12120-7 battery weighing 5 Kg and rated at 12V, 12AH would operate the system seven to twelve hours (depending mainly on display demand) before needing recharge. This would be adequate for the anticipated typical working day.

It may be possible to buy acceptable DC/DC converter modules to power the probe and electronics but we assume that these items will be designed in-house with intrinsic safety constraints. If the tools selected include one from a second manufacturer, a dual output converter with switching under software control may be needed.

4.6.3.2 The Processor

Since the rate of data accumulation will be relatively slow a basic processor, such as one in the 6800 series will be adequate. A CMOS version is indicated to minimise power demand. Along with the central processor a clock, a 12-bit analog to digital converter and interfaces with the display, the touch panel keyboard, the data storage memory, and the output port will be included. Software will be stored in ROM, EPROM being favoured as it is cheap to program and then if necessary, alter. Only a guess can be made as to the amount of ROM needed but it would be a few "K' which is a manageable amount. There will also be a kilobyte or so of scratch pad RAM.

Since none of the above constitutes an unusual requirement it is expected that a ready made board or set of boards would be selected. An example could be the Tattletale Data Logging Engine made by Onset Computer Corp. The display would be procured along with a matching "smart" interface board to reduce the load on the processor and the need to write expensive interfacing software.

4.6.3.2.1 Battery Back Up

The clock and, probably, the RAM will have its own small on-board battery so that it is protected when the main battery is discharged or disconnected. We do not anticipate problems with certification of these batteries if they are used.

4.6.3.2.2 Data Memory

This will utilise CMOS Static Random Access Memory (SRAM). The amount of memory needed is that for a day's work. A 300 metre long hole would take 100 minutes up and down at 6 metres/sec and a 100 metre hole 34 minutes. This indicates that at most 20 logs would need to be recorded in a day. To simplify the software it is proposed that sections of SRAM be allocated one for each pass each large enough to accommodate data from one pass up or down a maximum length 300 metre hole.

As indicated in Section 3.5.1.9.11, Data Storage, each log will fit into a "128K" block of RAM. This is a commonly used unit of RAM. It should be noted that since the RAM will be loaded sequentially RAM address will correspond to position in the hole.

To accommodate the expected work day maximum of 20 passes, 20 times 128K of RAM must be available; that is 2,560K. We propose to install 3 "Megabytes".

4.6.3.2.3 Serial Output Port

Physically this will be in the form of a connector which will be kept covered in the mine with a sealed cap to exclude dust. At the surface, the appropriate cable assembly will be used to link to the personal computer being used to organise the data. Regardless of the computer type, an RS 232 serial data link will be available capable of transferring data at 9600 Baud and, in some cases, also at 19200 Baud. To transfer the possible maximum (that is: 3 megabytes = 24M bits) of data at 9600 Baud could take 40 minutes; but, in most cases, the time taken should be acceptable, especially if simultaneous with battery charging.

4.6.3.2.4 Parallel Output Port

If installed, this alternative would use a specialized direct off-load facility of which an example is Onset Computer Corp.'s "Direct-6" which could transfer the full data load in parallel form in less than 1 minute into a PC-AT. This requires the PC to be fitted with a special plug-in card.

4.6.3.2.5 Analog Output

This will be derived from a two-pin connector with protective cover. Data will be latched out of the processor at intervals corresponding to 5 mm of log into a 12-bit digital-to-analog converter. The output from the converter will be low-pass filtered to the extent needed to smooth it and amplified and level shifted by pre-set internal controls to suit the external chart recorder to be used, typically an intrinsically-safe unit such as that manufactured by Rapco in the U.K. Additional software will be needed to service this output and make it possible to plot a log in real-time or plot from data previously stored in memory.

4.6.3.3 Signal Input and Conditioning

The signal from the tool must first pass through the cable in pulse form. and then it is conditioned by the interface circuitry into a form accessible to the processor.

4.6.3.3.1 Cable - Electrical Aspects

Armoured geophysical logging cable of standard 4.8 mm diameter, 4-conductor plus armour type will be used. This is the heaviest cable that can be accommodated and, at the same time, retain the required portability. It has relatively high conductor resistance (24 ohms for 300 m) but, by using three of the four conductors in parallel for the power with the armour (8 ohms per 300 m) as return, the DC drop will be acceptable. The fourth conductor will be used for signal, again with the armour as return. Use of the steel double armour as a signal and power return is standard in the industry. Cable capacitance at 194 Pf per metre is also high and causes pulse shape degradation. This will be less than that generally encountered in most borehole loggers since cable length will be only 335 m not 1,000 m as generally used.

4.6.3.3.2 Signal Conditioning, Analog Tool

The signal conditioning required depends on the particular tools selected.

The older tool types have a so-called analog output (see Figure 4.6.3.3.2). In these tools, for which Figure 4.6.2-2 represents an old but typical schematic, the pulses from the photomultiplier are preamplified, then amplitude selected by a discriminator. An output amplifier, often combined with a pulse shaper circuit, then puts the pulses on the cable. The amplifier and the matching network at the receiving end of the cable should be matched so as to minimize stretching and overlap of the pulses due to the effects of cable capacitance. Nevertheless, overlap and, consequently missed counts can occur with closely spaced events. This contributes to the overall "dead time" of the system. In this regard, it is helpful that the cable is relatively short with lower than the usual capacitance.

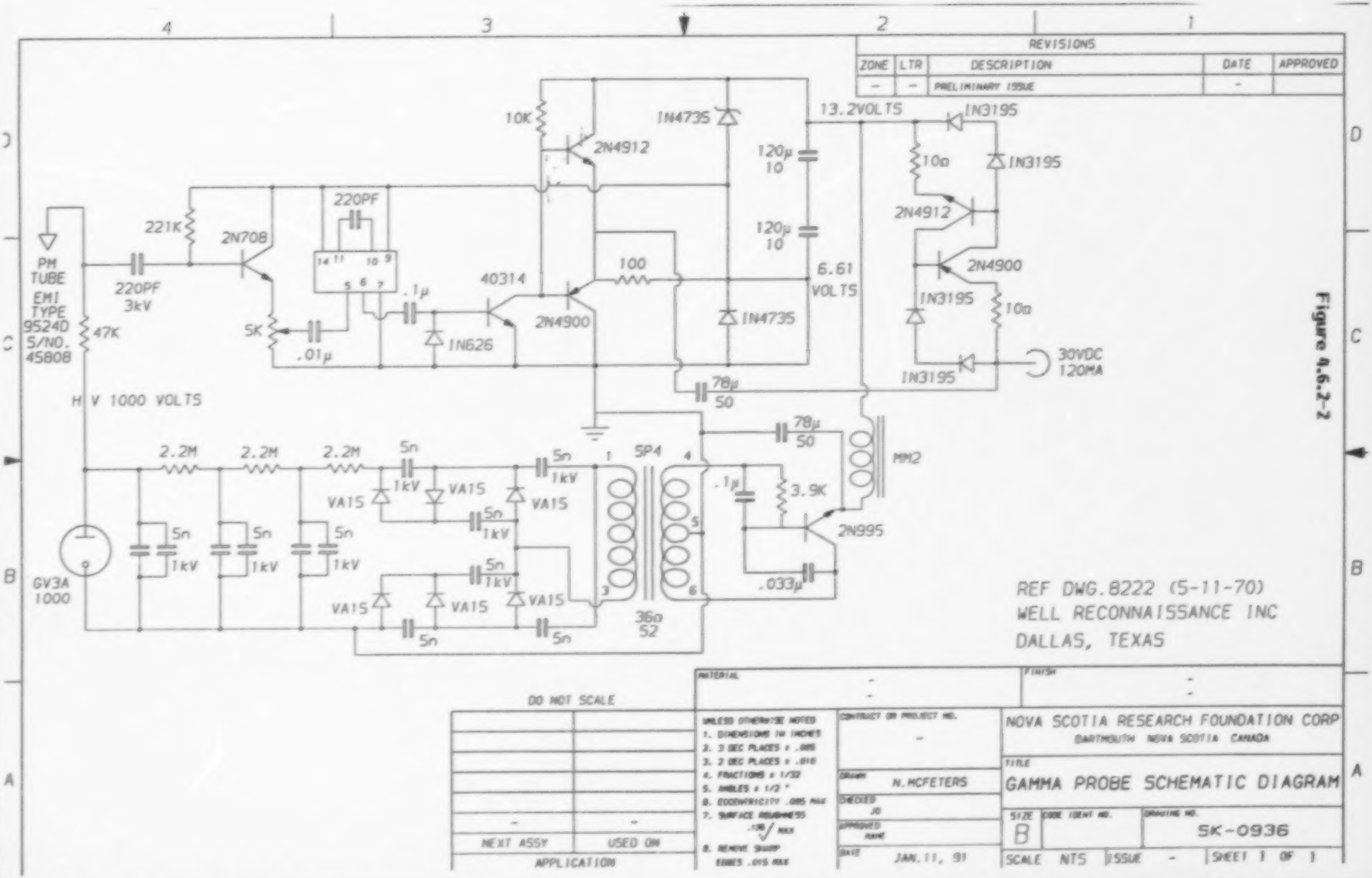
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
PRELIMINARY ISSUE
10K
2N4912
IN4735
13.2VOLTS
IN3195
120µ 10
120µ 10
10Ω
IN3195
2N4912
220PF
221K
2N708
14 11 10 9
5 6 7
PM TUBE
EMI TYPE 9524D S/NO. 45808
220PF 3kV
.1µ
40314
100
6.61 VOLTS
2N4900
47K
5K
.01µ
IN626
2N4900
IN4735
IN3195
10Ω
30VDC 120MA
IN3195
78µ 50
H V 1000 VOLTS
2.2M
2.2M
2.2M
5n
1kV
VA15
5n 1kV
SP4
1
4
78µ 50
MM2
.1µ
3.9K
2N995
5
3
6
36Ω 52
.033µ
GV3A 1000
REF DWG.8222 (5-11-70)
WELL RECONNAISSANCE INC
DALLAS, TEXAS
MATERIAL
FINISH
DO NOT SCALE
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE NOTED
1. DIMENSIONS IN INCHES
2. 3 DEC PLACES ± .005
3. 2 DEC PLACES ± .010
4. FRACTIONS ± 1/32
5. ANGLES ± 1/2°
6. ECCENTRICITY .005 MAX
7. SURFACE ROUGHNESS 125 MAX
8. REMOVE SHARP EDGES .015 MAX
CONTRACT OR PROJECT NO.
DRAWN N.MCFETERS
CHECKED JO
APPROVED NAME
DATE JAN.11, 91
NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA
TITLE
GAMMA PROBE SCHEMATIC DIAGRAM
SIZE B
CODE IDENT NO.
DRAWING NO. SK-0936
SCALE NTS
ISSUE -
SHEET 1 OF 1
A
B
C
D
1
2
3
4

Figure 4.6.2-2

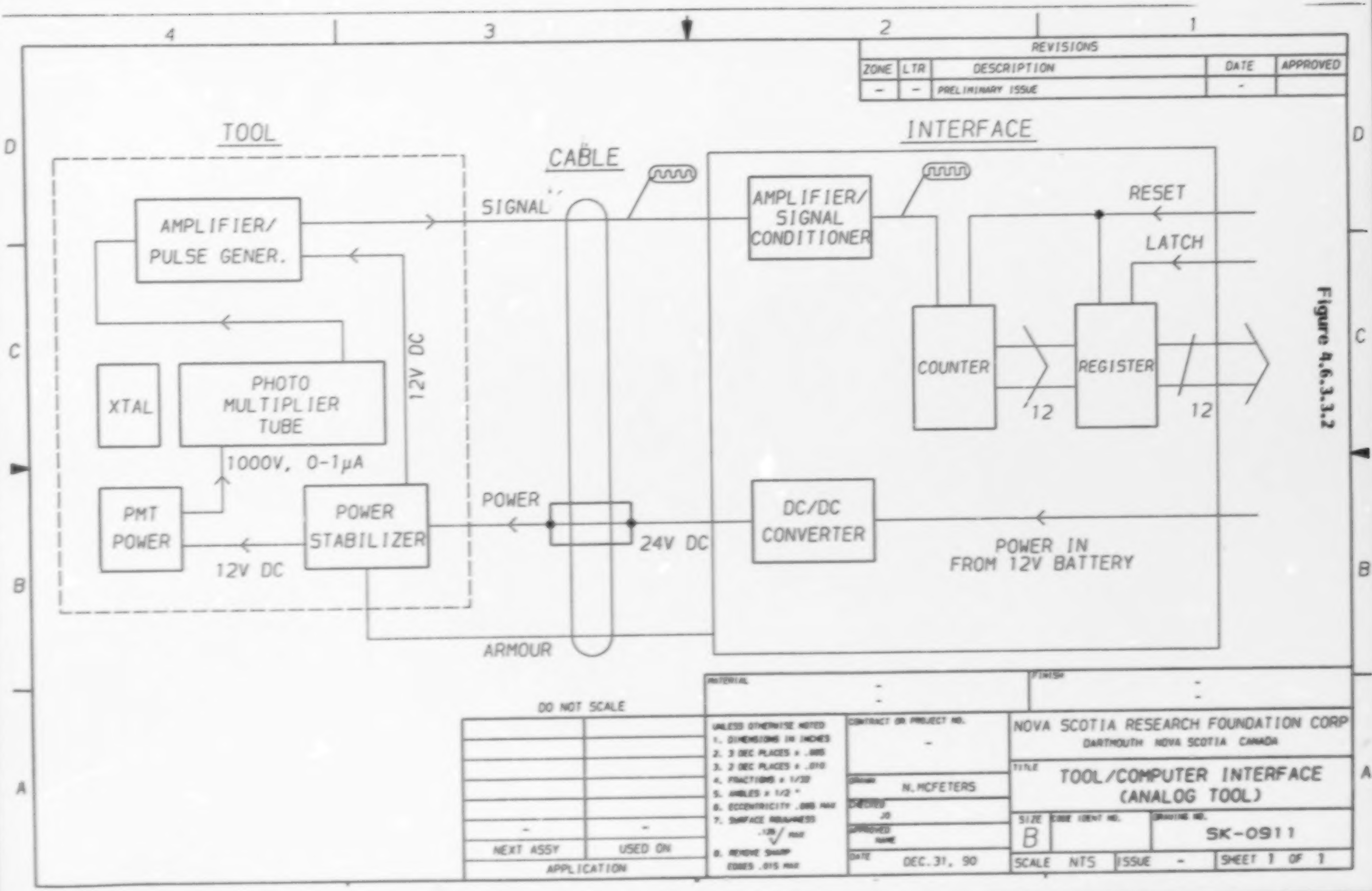

4
3
2
1
D
C
B
A
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
-
-
PRELIMINARY ISSUE
-
TOOL
CABLE
INTERFACE
AMPLIFIER/
PULSE GENER.
XTAL
PHOTO
MULTIPLIER
TUBE
1000V, 0-1μA
PMT
POWER
POWER
STABILIZER
12V DC
12V DC
SIGNAL
POWER
ARMOUR
24V DC
AMPLIFIER/
SIGNAL
CONDITIONER
COUNTER
REGISTER
12
12
RESET
LATCH
DC/DC
CONVERTER
POWER IN
FROM 12V BATTERY
DO NOT SCALE
NEXT ASSY
USED ON
APPLICATION
-
-
MATERIAL
-
-
FINISH
-
-
UNLESS OTHERWISE NOTED
1. DIMENSIONS IN INCHES
2. 3 DEC PLACES ± .005
3. 2 DEC PLACES ± .010
4. FRACTIONS ± 1/32
5. ANGLES ± 1/2 °
6. ECCENTRICITY .005 MAX
7. SURFACE ROUGHNESS
.125 MAX
8. REMOVE SHARP
EDGES .015 MAX
CONTRACT OR PROJECT NO.
-
DRAWN
N.MCFETERS
CHECKED
JD
APPROVED
NAME
DATE
DEC.31, 90
NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA
TITLE
TOOL/COMPUTER INTERFACE
(ANALOG TOOL)
SIZE
B
CODE IDENT NO.
DRAWING NO.
SK-0911
SCALE
NTS
ISSUE
-
SHEET 1 OF 1

Figure 4.6.3.3.2

In many logging systems, the "analog" pulses from the cable are converted into a true analog signal for chart recording by means of a rate meter circuit and in some cases this signal is then digitized using an analog to digital converter. For our application, these steps would be redundant. After the cable head signal is amplified and re-shaped, digital circuitry will be used to directly count the pulses. Under control of the processor the counter content will be periodically latched into a register and the counter will then be zeroed by a reset pulse. The register contents will then be transferred by the processor into memory.

4.6.3.3.3 Signal Conditioning, Digital Tool

A more modern technology is the use of all-digital tools (see Figure 4.6.3.3.3) and these would be preferable if otherwise suitable. In these tools, the counting is done in the tool and the periodic totals are sent along the cable in the form of serial data messages. After being re-shaped and buffered at the cable head these can be directly read into the computer. The main advantage from this approach, apart from its directness, is that the limitations of the cable as a data channel are avoided and, for instance, changes in cable length do not change the "dead time" and do not require changes in discriminator settings.

4.6.3.3.4 Winch Counter

This will use a slotted disc, or equivalent, mounted on a shaft with a measuring wheel round which the cable wraps. A pair of sensors, with appropriate circuitry, are used to distinguish between upward and downward motion. Usually an optical approach is practical provided the disc and sensors were well sealed to keep out dust. Alternatively, a combination of a slotted disc made of soft magnetic material with magnets and Hall sensors, such as the Sprague 3140T to detect field variations could be used. In either case, the pulses from the sensors will be the input of the circuit of Figure 4.6.3.3.4-1 contained in the Electronics Module.

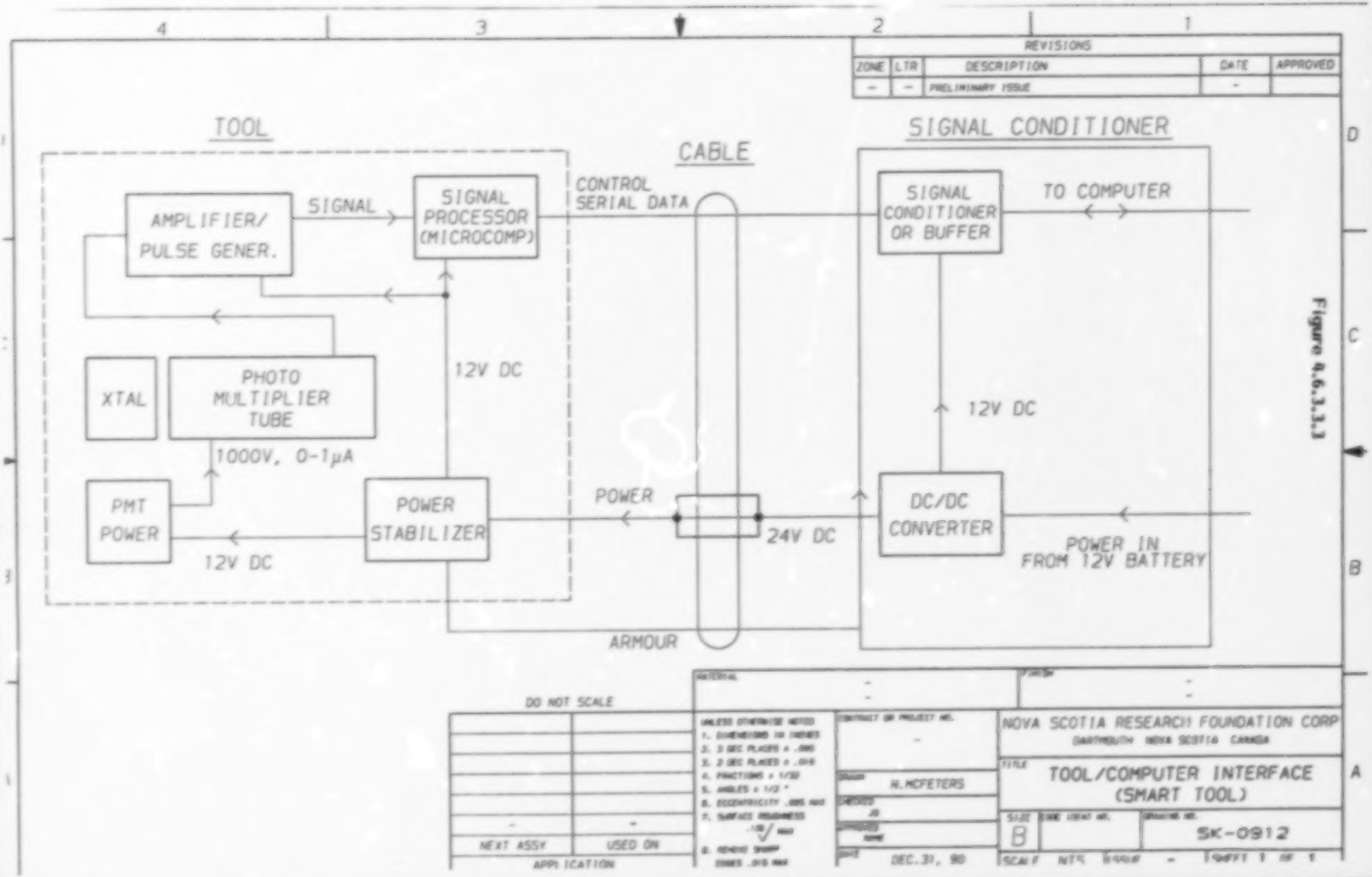

4
3
2
1
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
PRELIMINARY ISSUE
TOOL
CABLE
SIGNAL CONDITIONER
AMPLIFIER/ PULSE GENER.
SIGNAL
SIGNAL PROCESSOR (MICROCOMP)
CONTROL SERIAL DATA
SIGNAL CONDITIONER OR BUFFER
TO COMPUTER
XTAL
PHOTO MULTIPLIER TUBE
12V DC
1000V, 0-1μA
PMT POWER
POWER STABILIZER
POWER
24V DC
DC/DC CONVERTER
POWER IN FROM 12V BATTERY
ARMOUR
D
C
B
A
DO NOT SCALE
NEXT ASSY
USED ON
APPLICATION
H.MCFETERS
DEC.31, 90
NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA
TOOL/COMPUTER INTERFACE (SMART TOOL)
B
SK-0912
NTS
SHEET 1 OF 1

Figure 4.6.3.3.3

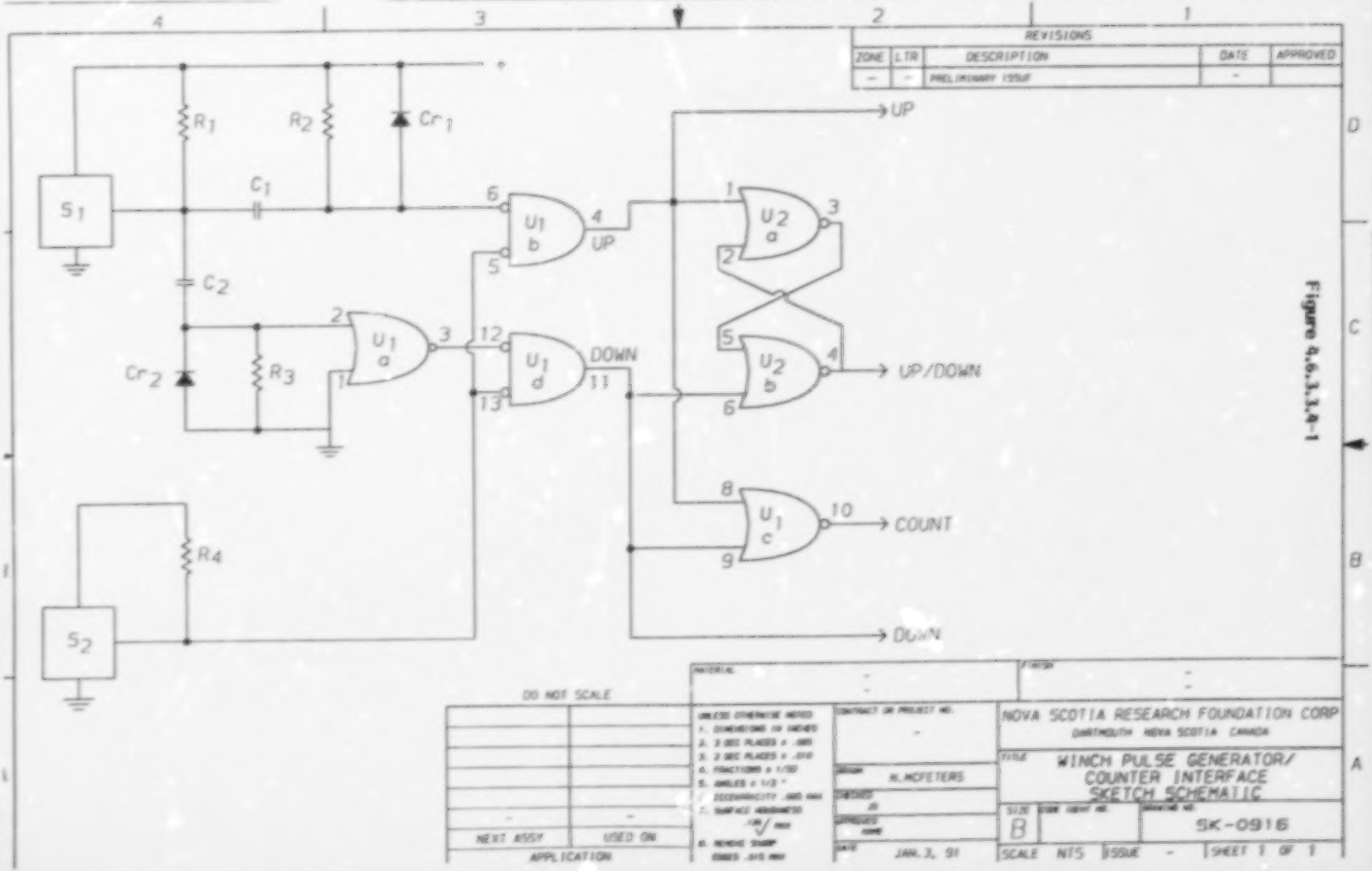


Figure 4.6.3.3.4-1

4
3
2
1
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
PRELIMINARY ISSUE
D
C
B
A
S1
S2
R1
R2
R3
R4
C1
C2
Cr1
Cr2
U1 a
U1 b
U1 c
U1 d
U2 a
U2 b
UP
DOWN
UP/DOWN
COUNT
DO NOT SCALE
NEXT ASSY
USED ON
APPLICATION
H.MCFETERS
JAN.3, 91
NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA
WINCH PULSE GENERATOR/
COUNTER INTERFACE
SKETCH SCHEMATIC
SIZE B
SK-0916
SCALE NTS
ISSUE -
SHEET 1 OF 1

The geometry of the disc and sensors S1,S2 is such that the two output pulses overlap as shown in a) and b) of Figure 4.6.3.3.4-2. The falling edge of S1's output pulse is differentiated by C1 and R2 to provide a narrow negative "edge" pulse at the input of gate U1b. The rising edge of S1's pulse is differentiated and inverted by C2, R3 and U1a to produce a narrow negative edge pulse at the input of U1d. Depending on rotation direction, the pulse from S2 occurs at the correct time to strobe the edge pulse into either U1b "up" or U1d "down". Positive Up and Down pulses are thus available from the outputs of U1b and U1d. If the disc happens to reverse during the period of the pulses no net count should result. The various possibilities are sketched in Figure 4.6.3.3.4-2 c) to h) and it will be seen that either no pulse is produced or one each of up and down pulses for a net count of zero.

In U1c, up and down pulses are combined to produce (negative) Count pulses. U2a and b form a flip flop, the state of which signals whether the count is up or down. These circuits may or may not be needed depending on the logic of the following up/down counter.

Under control of the processor the counter contents will be periodically latched out and read by the processor.

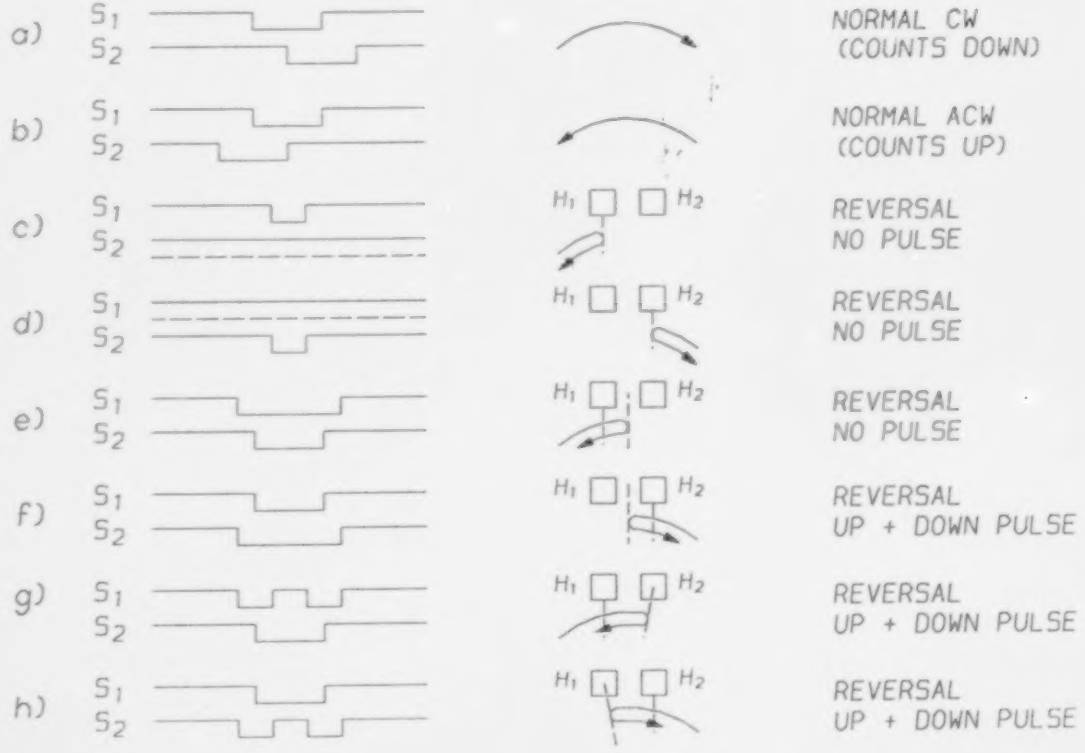
4.6.3.4 Touch Panel

This would have to be carefully selected to achieve the needed level of ruggedness and sealing but a variety of models intended for factory use is on the market. A full alpha-numeric panel is required so that header information etc. can be input.

4.6.3.5 Display Panel

Liquid Crystal Display panels are now available from several makers in sizes up to 720 x 480 dot pixels (Optrex). Also available are electroluminescent panels in similar sizes. A panel such as 512 x 256 would be adequate to show the required three side-by-side plots (i.e.: gamma ray, gamma-gamma/density, and neutron-neutron). It would be purchased with electronics for interfacing and control and a matching inverter. Viewing area for the module will be of the order of 125 x 100 mm. The LCD panel would need to be back illuminated with LEDs. As well as the analog display of data, the panel will also be used to show alpha-numeric messages and prompts.

Figure 4.6.3.3.4-2


a) S1 S2 NORMAL CW (COUNTS DOWN)
b) S1 S2 NORMAL ACW (COUNTS UP)
c) S1 S2 H1 H2 REVERSAL NO PULSE
d) S1 S2 H1 H2 REVERSAL NO PULSE
e) S1 S2 H1 H2 REVERSAL NO PULSE
f) S1 S2 H1 H2 REVERSAL UP + DOWN PULSE
g) S1 S2 H1 H2 REVERSAL UP + DOWN PULSE
h) S1 S2 H1 H2 REVERSAL UP + DOWN PULSE

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
-	-	PRELIMINARY ISSUE	-	

DO NOT SCALE

NEXT ASSY	USED ON
-	-
APPLICATION	

MATERIAL - -

FINISH - -

UNLESS OTHERWISE NOTED
1. DIMENSIONS IN INCHES
2. 3 DEC PLACES ± .005
3. 2 DEC PLACES ± .010
4. FRACTIONS ± 1/32
5. ANGLES ± 1/2 °
6. ECCENTRICITY .005 MAX
7. SURFACE ROUGHNESS .125 √ MAX
8. REMOVE SHARP EDGES .015 MAX

CONTRACT OR PROJECT NO. -

DRAWN N.MCFETERS

CHECKED JO

APPROVED NAME

DATE JAN.3, 91

NOVA SCOTIA RESEARCH FOUNDATION CORP
DARTMOUTH NOVA SCOTIA CANADA

TITLE WINCH PULSE GENERATOR/ WAVE FORMS

SIZE B

CODE IDENT NO.

DRAWING NO. SK-0917

SCALE NTS

ISSUE -

SHEET 1 OF 1

From the user point of view, there is little to choose between the two panel types although the LCD panels do consume less power and the choice would be part of the detailed prototype design process.

4.7 Conceptual Design - In Mine Logger Software

4.7.1 Requirements and Specifications

4.7.1.1 General

This software is intended to operate with the "IN MINE LOGGER" system. Its primary function is to acquire raw count data samples from the logging probe and to store them in random-access memory (RAM). It also provides the user with a real-time graphical data display. Finally, there is a data transfer capability for storing the samples on an IBM-compatible PC.

4.7.1.2 Data Logging

The winch operates in data logging mode with a normal top speed of 10 m/min, and with an elevation resolution of 0.5 cm. This means a maximum time sampling rate of 34 samp/s or 30 msec/samp. The program must acquire a 12-bit sample, convert it to 2-byte format, and save it in the correct memory location within 30 msec. The newly acquired data sample, and its corresponding elevation, are displayed graphically at the same time.

If the normal winch speed is exceeded, the program generates a warning message, and continues to acquire data at the best rate it can manage.

If an error is detected in the winch position/movement data (eg: a stall condition), the program displays an error message and modifies the data sample with the appropriate error flag.

The on-screen elevation indicator remains active during all modes of winch operation, even if a probe is not attached.

4.7.1.3 User Interface

Communication with the logger system is via a keyboard/panel. This panel should have a standard QWERTY layout, since the user must provide documenting header data. In addition, the user controls data acquisition using a menu structure which permits access to all of the data logger's functions.

The user may request that data acquisition and storage be suspended, for example during times when the probe is being re-positioned at high speed. An on-screen reminder is displayed when data logging is deactivated.

When a log is complete, the user may request to see scrolled data displays, starting at any elevation along the log. However, since the logging direction can be reversed at any elevation during the log, multiple occurrences of the same elevation will be recorded in separate branches of the log (see Section 4.7.2.6 below).

Vertical display units are meters or tenths of meters, and horizontal display units are counts per second and/or calibration units for the probe. The user can specify arbitrary scale factors for both display axes, although the program provides default values. Up to three logs can be scrolled side-by-side on the screen, and a grid is superimposed on the display as on standard chart paper.

4.7.1.4 Data Storage & Transfer

Data samples are stored in RAM in binary format, 12 data bits per 2-byte packet. To facilitate data analysis, it is necessary to transfer the data to a PC and store it in a format that is accessible to a variety of processing software (eg: Fortran, Lotus 123). This requires translation from binary format to ASCII-text format.

The data transfer section of the program must read RAM locations sequentially, send the data bytes to the PC via serial or parallel link, and allow time for the PC to store the binary data in a hard disk file.

4.7.2 Principal Software Modules

The logger program comprises several modules in order to organize and isolate unique processing tasks. While it is not possible to design a module chart at this stage, the major module sections are outlined here, each section requiring several program modules.

4.7.2.1 Initialization

The initialization section performs essential processor diagnostics to ensure system integrity and, if possible within a 5 to 10 minute period, a RAM memory test. Then the user menu is displayed, with an automatic entry into the Header Data Segment (section F. below) input screen if data logging has been requested.

In addition, calibration tests may be requested for the logging probes to ensure they are operating correctly. Gamma probes are calibrated in API units (0 - 200), density (gamma-gamma) probes are calibrated in gm/cc, and neutron-neutron probes in % porosity units.

4.7.2.2 User Interface

This section controls processing of the user's menu requests through the control panel. It supervises the entry of user information, including the header and footer data. It also controls the display of all menus, header and footer data, sampled data graphs, and real-time warnings and error messages.

To be prepared for a 'sufficiently' critical system failure (jammed winch, broken cable, etc) the interface maintains, at all times, the capability for the user to completely shut down the data acquisition process and secure the existing data in RAM memory.

4.7.2.3 Data Acquisition

Within the 30 msec sampling window, this section checks the winch position counter, waits until the next 0.5 cm elevation increment, and acquires the corresponding count reading from the probe. The data sample is stored in the correct RAM location and the process repeats. It is preferable to have the data acquisition modules triggered by an external hardware interrupt from the winch controller or the signal conditioning circuitry. This avoids using a scheduling algorithm and polling the data acquisition board within the correct time frame.

4.7.2.4 Data Display

This section produces a scrolled data chart on the display panel in real time as data is acquired. It also generates an elevation-only display in order to perform borehole elevation checks. The data scrolls can start at any elevation branch in the log.

Header and footer information can also be displayed at the user's request for any specified log.

At least 100 pixels should be used on the horizontal data axis for each of three side-by-side data scrolls. This requires a minimum of 300 pixels in the horizontal panel direction.

A smart panel should be used so that ASCII character codes can be used directly, rather than having the logger program convert from characters to pixel patterns. Pixel translation requires the preparation and storage of a large character set pixel table.

4.7.2.5 Data Transfer

This section transfers all of the data (headers, data samples, and footers) stored in RAM to an IBM-compatible PC. The data is transferred via serial link at 9600 baud, or by a parallel link at higher baud rates. A supplementary program must also be written or purchased for the PC so that it can capture the incoming data and store it in a hard disk file.

Converting from binary data to ASCII-text should be done by a utility program after the data transfer is complete. This avoids a time-consuming process interfering with data acquisition and data transfer, each of which have their own timing constraints.

Data transfer to floppy disks is not recommended. The expected volume of data makes it impractical to swap disks, especially if data transfer is done overnight at low baud rates. Data can be backed up to floppies after the transfer is complete, using MS-DOS Backup or a commercial backup program.

4.7.2.6 Data Structure In RAM

Each data log consists of three segments:

Log header segment
Sampled data segment
End of log footer

The header segment contains the log name, location, borehole #, date, time, initial elevation offset, calibration data, etc. This section requires a few hundred bytes of RAM.

The sampled data segment contains two-byte packets for each sample. Each packet contains 12 bits of count data for the sampling interval. Each packet also contains control information in the high four bits for change in direction flags, critical hardware failure flags, etc. Elevation data is not stored, but is implied in the sample's memory address: each 2-byte increment in the address space corresponds to another 0.5 cm elevation increment. This segment needs about 800 KB of RAM for each log, to a maximum of three logs per day.

In order to uniquely identify portions of the log which have identical elevations (section I C. above), the log is divided into branches, each identified by a branch header containing:

G,N, or D: 1 letter denoting the type of log
n: 1 digit denoting the branch number
U or D: 1 letter denoting the logging direction
ssss.s: a 5-digit starting elevation
eeee.e: a 5-digit ending elevation

The user selects a branch for data scrolling by specifying the first three branch header characters, eg: N6D denotes a neutron-neutron log, branch 6, descending.

The footer contains additional descriptive information about events during the log, a second set of calibration data, a second elevation offset, etc.

4.7.3 Software Development

The in mine logger software is to be developed using a high-level language such as C or Pascal. The use of assembly language is not recommended unless it is necessary to re-code specific modules when they are not fast enough. There are two main approaches applicable to this project, depending on the choice of field system/development system.

The first approach assumes the use of a stand-alone processor/data acquisition board (or boards). Program development is done on a separate PC using a suitable cross-compiler (eg: Archimedes "C"). The compiled program code file is transferred to a PROM programmer, and the PROM chips installed on the processor's memory board.

The second approach is to use a flameproof IBM-compatible PC laptop and a standard data acquisition board (eg: Tecmar LabMaster). With 'expanded' memory installed (3-4 MB), the program writes directly to a RAM disk drive emulator (eg: RAMDRIVE in MS-DOS). The program is compiled with a standard MS-DOS language (eg: Turbo Pascal, Turbo C).

4.7.4 Software Conclusions & Recommendations

1. The next phase of software development is to prepare the final version of the Requirements Profile. This will define in detail what the software must do and what functionality is to be provided to the user.

   As the hardware specification, particularly the electronics/processor have not yet been finalized, the Requirements Profile cannot be completed.

   It is recommended that the hardware specifics be finalized as soon as possible so that effective software development can begin.

2. The second phase of software development will be to prepare the Design Profile. This will define in the detail the software technical details, modularization, and detailed menu/screen layouts for the user interface.

   This phase is entirely dependent on completion of the Requirements Profile.

3. The time and costing estimate provided in the Conceptual Design is very rough. A proper cost/time estimate can be prepared after completion of the Design Profile.

   It is recommended that a time/cost estimate be prepared for doing the Requirements Profile, the Design Profile, and software development/implementation as each previous phase is completed. If this cannot be scheduled, then the time/cost estimate will have to be done when the Design Profile is complete.

4.8 Documentation

The following is an outline of the documentation envisaged for the design and fabrication phase of this project:

1. In order to facilitate evaluation of the prototype, a set of operating and maintenance manuals will be prepared.
2. A complete set of computerized working drawings will be produced.
3. In order to assist production in such ways as showing wiring layouts, a set of colour photographs of the prototype will also be assembled.

5 MARKET STUDY

5.1 Introduction and Background

This market study attempted to identify current technology and practices used by the mining industry in geophysical logging, quantified the global market potential for the proposed geophysical logging system, and identified barriers to market entry. Interest and capabilities of various companies in manufacturing the equipment was assessed.

Over 150 individuals and organizations were contacted during the market study. Through the use of geophysical contractor directories, over 40 major world-wide geophysical contractors and manufacturing companies were contacted for information on existing equipment, indications of the demand for in-mine logging services and interest in manufacturing or distributing the proposed logging system. In addition, about 25 major mining and geophysical research centres throughout the world were contacted for information on the existence of in-mine borehole logging equipment, potential applications of in-mine borehole logging and the potential demand for the proposed system. Coal research organizations in Canada, the U.S.A., France, Germany and England were also contacted. National Research Council of Canada Technology Advisors and Commercial Representatives in over 40 Canadian Embassies throughout the world were asked for information on major geophysical contractors and manufacturers, mining research organizations and working coal mines thought to require in-mine borehole logging services. A telephone survey was conducted of all major coal mining operations in Canada, the U.S.A., and the United Kingdom.

Both computerized and manual literature searches were undertaken to identify geophysical equipment used for in-mine borehole logging as well as statistics and information on the volume of in-mine borehole mining undertaken. A technology patent search through Consumer and Corporate Affairs, Ottawa, was carried out to identify patents on previously developed in-mine borehole logging systems.

5.2 State of the Industry

5.2.1 General

Overall, there was a very good response to our inquiries from geophysical contractors concerning the existence of in-mine borehole logging equipment and the market demand for this equipment. A large number of borehole logging systems have been developed and are in use by geophysical contractors and mines throughout the world. Most logging is done from the surface in a downward direction. The probes are lowered into the borehole, then winched back at a controlled speed so a geophysical log of the hole may be measured. Difficulties are encountered when logging probes are placed in horizontal or upward drill holes, as gravity works against inserting the probe into the holes. The uniqueness of the system being developed is the ability to insert a probe into a borehole at any angle and to have an explosion proof/intrinsically-safe, portable system that may be used in a coal mine.

In-mine borehole logging was viewed as a very specialized area with minimal market potential in North America. Geophysical contractors expressed a variety of opinions as to the best equipment for borehole logging. Many logging techniques in addition to gamma-ray, gamma-gamma, and neutron-neutron probes are available in the market place, each with its own strengths and weaknesses. Several articles found in the literature searches discuss the pros and cons of various exploration techniques. In North America, almost all geophysical borehole logging is conducted from the surface and there appeared to be few opportunities for in-mine logging. Responses from the coal industry varied considerably, indicating the wide spectrum of sophistication in techniques employed by coal mines in geophysical investigations. Many mines contacted did not use borehole logging as a method of investigation, nor were they interested in pursuing the matter further.

5.2.2 Current Equipment and Technology

5.2.2.1 General

There are primarily three groups of methods for exploration ahead of the mine face: mining, geophysical and mathematical modelling and analysis. Mining methods include not only the drivage of exploratory roads in coal or stone but also all types of boring, such as exploratory boring from the surface or from underground. The latter is subdivided into: in-seam boring instead of exploratory roads in coal; horizontal or directional long-hole boring (greater than 500 meters); omni-directional fan boring of an average length less than 500 meters; and inter-seam boring in a grid pattern for the aerial exploration of the structure of adjacent workable seams.

Geophysical methods are subdivided into surface reflection seismics, underground seam wave seismics, and geophysical measurements in boreholes from the surface and underground.

The third group, mathematical modelling and analysis methods, mainly comprises trend calculations and interpolation on the basis of available data about the deposit.

5.2.2.2 Measurement While Drilling

An evolving technology is Measurement While Drilling (MWD). An article in Exploration and Production Technology International (Gibbs, 1990) indicated that Measurement While Drilling represents a $200 million dollar business world-wide. Most conventional MWD tools are powered by a downhole turbine and transmit all the data to the surface through pressure pulses in the moving mud stream. Recent developments in packaging of advanced downhole electronics and sensors have led to a new generation of sophisticated multi-sensor tools for formation evaluation. Logging while drilling (LWD) ensures an early record of the petrophysical data when drilling is taking place. LWD sensors are generally battery powered for continuous operation. Data are stored in a non-volatile downhole memory, and key information may be transmitted to surface in real time. Schlumberger has recently introduced a new multifunction probe capable of measuring several parameters simultaneously. This system generates a log that can significantly impact drilling efficiency and safety.

5.2.2.3 Moving Probes

Through literature searches and discussions with geophysical contractors, there were identified four methods for pushing a geophysical probe in a borehole that was either horizontal or above the horizon: (1) push the probe using endless plastic tubing, wire, or metal/plastic push rods; (2) use hydraulic pump pressure with water, air or mud to push the probe along the borehole; (3) use the drill string for inserting the probe into the borehole; (4) use a pulley system.

The most-frequently mentioned method of inserting a probe into a horizontal or above-horizontal borehole was the use of plastic or metal push rods. The geophysical probe is connected to the end of the push rod and inserted into the borehole, where additional rods are connected to achieve the desired depth. Push rods were considered bulky, difficult to use and normally used to a maximum distance of 300-400 feet. Continuous logging is usually impossible with push rods, due to the difficulty of a controlled withdrawal speed. A variation on the push rods includes teleflex steel (similar to a sewer snake) or storable tubular extendable members (STEM) which are similar to two tape measures which roll into tubes when unwound from a reel. Endless plastic tubing was also used by some geophysical contractors for pushing probes into boreholes. This tubing had the advantage of being wound on a drum or a winch, thus being more compact and easier to handle. Canadian Fracmaster, Calgary, produces coil tubing which is used primarily in the oil industry to push geophysical tools in horizontal wells. The tubing is similar to the metal cable that protects electrical wire.

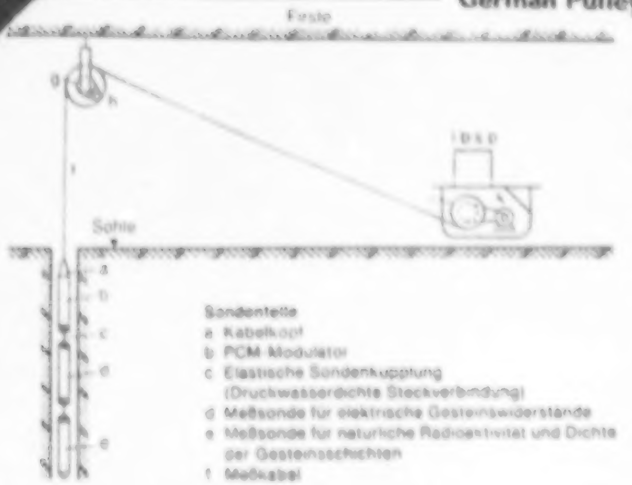
Another method identified for inserting probes into boreholes included a single or double pulley system. Pulley systems can achieve better distances than push rods and have the ability to maintain good speed control over the geophysical probe. Normally, the pulley is inserted into the end of the borehole using the drill string and the geophysical probe is then pulled down the hole using a winch. The German mining industry has developed particularly sophisticated pulley systems as shown in Figure 5.2-1. Quantech Consulting Inc., Mississauga, Ontario, has used a pulley system up to 4,000 feet, but difficulties were encountered with twisted cord.

Hydraulic systems have been used by some companies for inserting probes. Sondex Well Logging Instrumentation, England, has used water pressure, but reported difficulty in obtaining a smooth log as it was difficult to control the speed of the probe. Roke Oil Enterprises, Calgary, Alberta, have used a hydraulic system for pushing probes and have had considerable success although this system is expensive. Quantech Consulting Inc. also developed a hydraulic system. COLOG Inc., Golden, Colorado, uses water pressure to pump logging tools up boreholes.

5.3 Identified Geophysical Borehole Logging Equipment

Through a combination of literature, technology patent searches and contact with geophysical equipment manufacturers and research organizations, a number of products were identified which have been developed to perform similar functions to the equipment being designed.

Figure 5.2-1
German Pulley System



Sondenteile
a Kabelkopf
b PCM-Modulator
c Elastische Sondenkupplung (Druckwasserdichte Steckverbindung)
d Meßsonde für elektrische Gesteinswiderstände
e Meßsonde für natürliche Radioaktivität und Dichte der Gesteinsschichten
f Meßkabel

Umlenkrolle
g Rolle – PULLEY
h Teufenzähler
Meßkabelwinde
i Meßkabeltrommel
k Lamellenmotor

Registerteil
l PCM-Demodulator
m Kassetten-Magnetbandgerät
n Teufenanzeige
o Tastatur
p Stromversorgung, Batterie (Sch) s. i

Bild 4. Messung in abwärts gerichteten Bohrungen. Schematischer Aufbau mit Sonden, Umlenkrolle, Meßkabelwinde und Registrierteil.

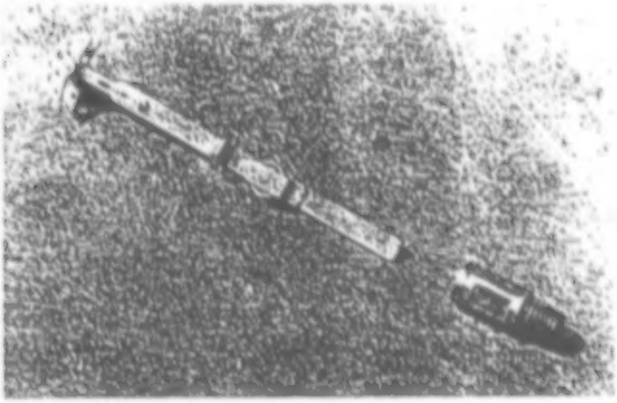
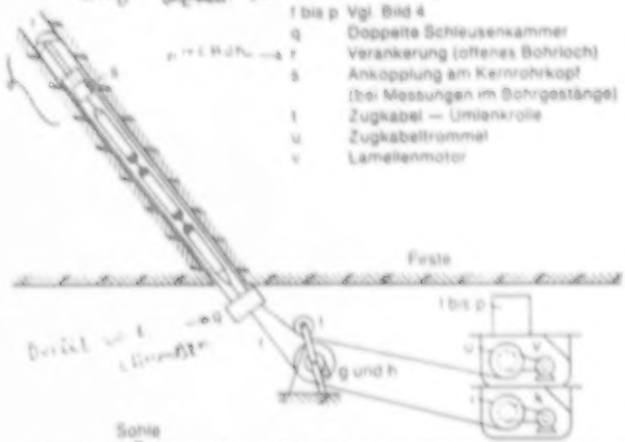


Bild 5. Umlenkrolle mit Klemmkeil (links oben) und Adapter für Messungen im horizontalen bzw. aufwärts gerichteten Bohrloch.

ADAPTOR FOR MEASUREMENT IN HORIZONTAL AND ~~[illegible]~~ UPWARDS HOLES



f bis p Vgl. Bild 4
q Doppelte Schleusenkammer
ANCHOR → r Verankerung (offenes Bohrloch)
s Ankopplung am Kernrohrkopf (bei Messungen im Bohrgestänge)
t Zugkabel — Umlenkrolle
u Zugkabeltrommel
v Lamellenmotor

Bild 6. Schematischer Aufbau für Messungen im offenen Bohrloch (r) und im Bohrgestänge (s) am Beispiel einer aufwärts gerichteten Bohrung.

loch eingebracht. Mit der Meßkabelwinde werden die Sonden bei der eigentlichen Meßfahrt wieder herausgezogen. Meß- und Zugkabel werden durch eine speziell konstruierte Schleusenkammer geführt, so daß die Messung im mit Spülung gefüllten Bohrloch durchgeführt werden kann.

Bei Messungen im Bohrgestänge wird die Umlenkrolle an einem modifizierten Kernrohrkopf befestigt (Bilder 6 und 7). Der Kernrohrkopf wird eingespült und rastet am Ende des Gestänges ein. Danach wird die Sonde einge-

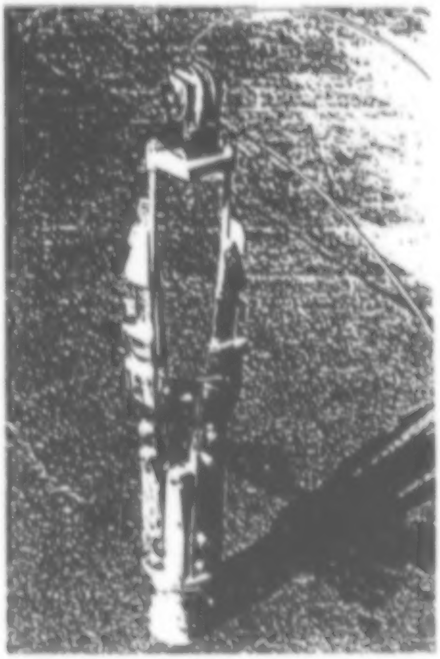


Bild 7. Modifizierter Kernrohrkopf mit Umlenkrolle.

MODIFIED CENTRAL CORE WITH PULLEY

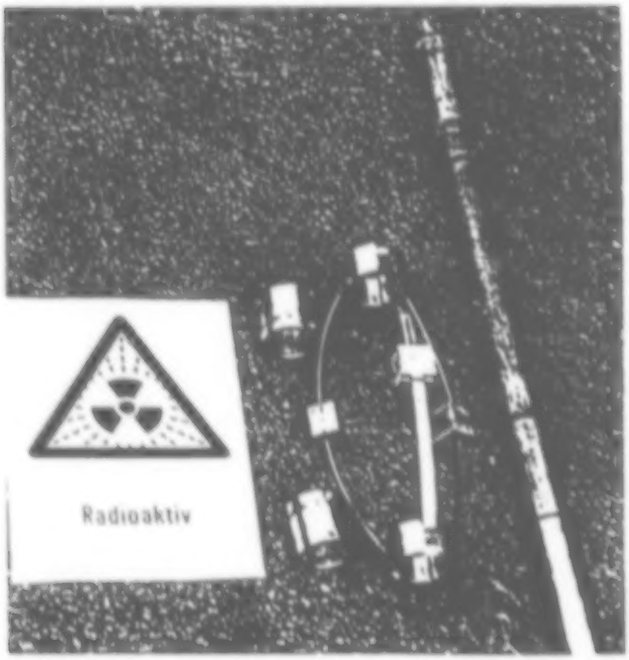


Bild 8. Gamma-Ray-Kaliber-Sonde mit den drei Strahlern und den beiden Szintillationskristallen.

5.3.1 North America

5.3.1.1 Canada

Two Canadian patents appeared to be particularly applicable to this study. The first, Patent 396,404 (issued 85 06 04 and granted to Grathnail Development Company Ltd., UK) by Guy LeBlanc Smith, and Derick Howard, South Africa is entitled "Method of An Apparatus for Mining Analysis." The purpose of the invention is to provide an improved method of mining analysis in an underground mine, by forming a plurality of boreholes in pre-determined directions in rock ahead of a rock face in the mine, at least one of the boreholes being at an angle to the other boreholes, for each borehole, locating a probe in the borehole, causing the probe to move along the borehole and logging data within the borehole. The probe is forced along the borehole by means of rigid push rods or alternatively the probe may be moved by the use of pressurized fluid. Analysis of the data from the log may take place on site or the recorded data may be conveyed to the surface for processing. The push rods may be arranged in a rack with a toothed gear which pushes them into the borehole (see Figure 5.3.1-1). A recorder is used to record the movement of rods and thus determine the position of the probe in the borehole. The authors of the patent also suggest that drill rods could be fitted with magnets at regular intervals and the passage of the magnet sensed by a detector and recorded in order to know the distance of the probe within the borehole. A variation on the design is a simple roller which is frictionally engaged with the rods which in turn will push the probe into the hole. The invention is to be used with coal mining and, therefore, is flame proof for use in dangerous areas. Once the probe has reached the desired position in the borehole, it is retracted in a controlled manner by tension on cable 42 (see Figure 5.3.1-1). Where the probe is employed in overhead boreholes, it can be prevented from running down the borehole under the action of gravity simply by having it frictionally engage the inner wall of the casing. Such a tight engagement also acts as a seal to prevent the pressurized liquid by-passing the probe. Data from the probe can be transmitted to the recorder via hard-wire techniques or replaced by a radio transmitter or transponder carried in the probe. If push rods are employed, they could be metallic or having metallic elements imbedded in them, to act as a conductive guide for the propagation of radio waves. Similarly, if a probe is in a metallic casing, the casing will function as a wave guide-type structure and assist the propagation of the radio waves, at least over reasonable distances. The data produced with the apparatus of the invention may be processed rapidly by means of a computer on-site or on surface and, once processed, the data is utilized at the face for optimum mining of the ore body. The advantage of the invention lies in the fact that the ore body or bodies are sampled in all directions from the mining face, in a rapid, accurate and simple manner.

Figure 5.3.1-1
Toothed Wheel with Push Rods
CDN Patent 1,188,364, Issued 85 06 04

1188364

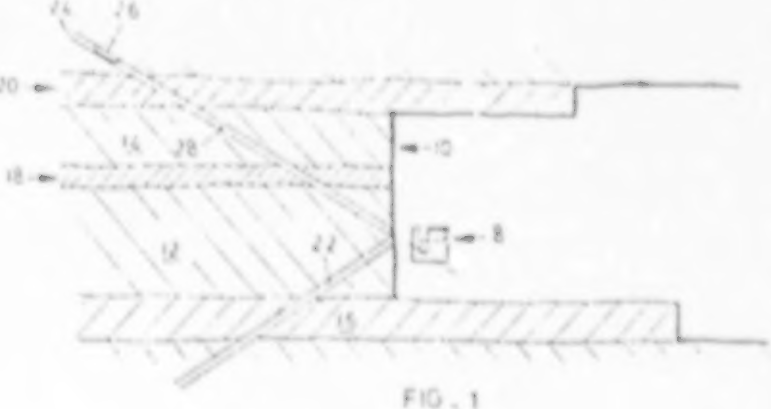

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FIG. 1

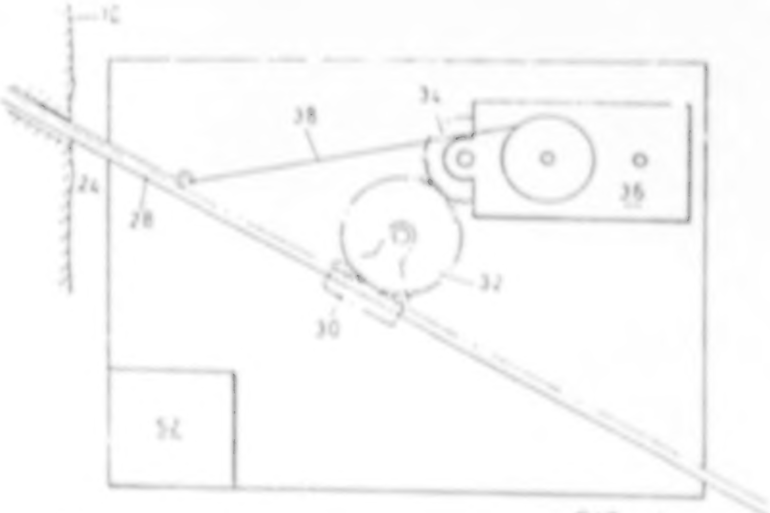
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FIG. 2

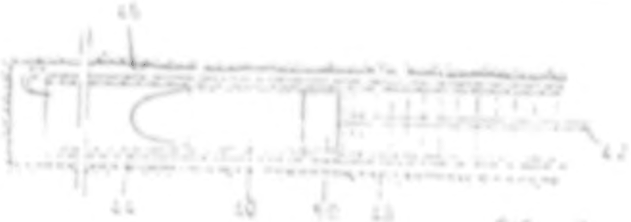
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FIG. 3

The second Canadian patent (No. 1,218,294, issued 87 02 24 to Mason, Charles E., USA, granted to CONOCO Incorp., USA, entitled Pump-Down Tool and Check Valve) is a valve system to be used when pumping a survey probe into a borehole and recovering it, particularly in horizontal or upward situated boreholes. The invention consists of a valve and sealing device which are provided for attachment to a cable connector which in turn is connected to a survey probe pumped down through a drill string conduit. The valve and sealing device is comprised of a valve having a slidable piston therein and a sealing swab extending outwardly from the valve housing. The cable extends through the valve to a connector joining the valve to a survey probe. The cable is adapted to move longitudinally with the valve piston in the valve. The valve and sealing device is pumped through the conduit, forcing the survey probe ahead of it and then it is retrieved with the valve portion in the open position to reduce resistance from fluid in the conduit. Figure 5.3.1-2 shows the design of the pump down tool and check valve. This type of system is in use by the Hudson's Bay Mining and Smelting Company in Flin Flon, Manitoba.

Computalog Manufacturing Ltd., Calgary, Alberta, have constructed an in-mine, explosion-proof borehole logging system for the Tar Sands Project funded by AOSTRA (Calgary and Fort McMurray) Program run by the Alberta provincial government. Although specifications and a detailed description of the borehole logging system were not available, two photographs of the in-mine part of the system are shown in Figure 5.3.1-3. This system consists of a winch, cable, slip-ring and winch operating system in a steel frame designed to protect the system and operator in the event of roof collapse. The system collects data and transmits it along a 500-meter long cable to recording equipment at the surface of the mine. Communication between the in-mine and surface operators is by radio or radio-telephone. This system would likely be unacceptable for in-mine logging in Cape Breton due to the distance between the areas to be logged and the surface (1.0-1.5 miles) together with the conveyor belt systems, railway, airlocks and other equipment in the access tunnels in a coal mine. Computalog have logged horizontally and upwards with this system but were unable to achieve an angle in excess of 30° above the horizontal. Both push rods and a water pumping system were used to force the probe into the borehole. The minimum hole diameter used with this system is 5-1/2 inches and the tool diameter is 2-3/4 inches which are too large for NQ and BQ diamond drill holes, as required in the Cape Breton Coal Mines. A major redesign would be required to downsize this system for diamond drill holes used for coal exploration in Nova Scotia. In addition, the suite of logs required for Nova Scotia coal investigations are not available on this logging system. Computalog designs and manufacturers the probes and modules in Forth Worth, Texas.

Figure 5.3.1-2
Pump Down Tool & Check Valve
CDN Patent 1,218,294, Issued 87 02 24

1218294

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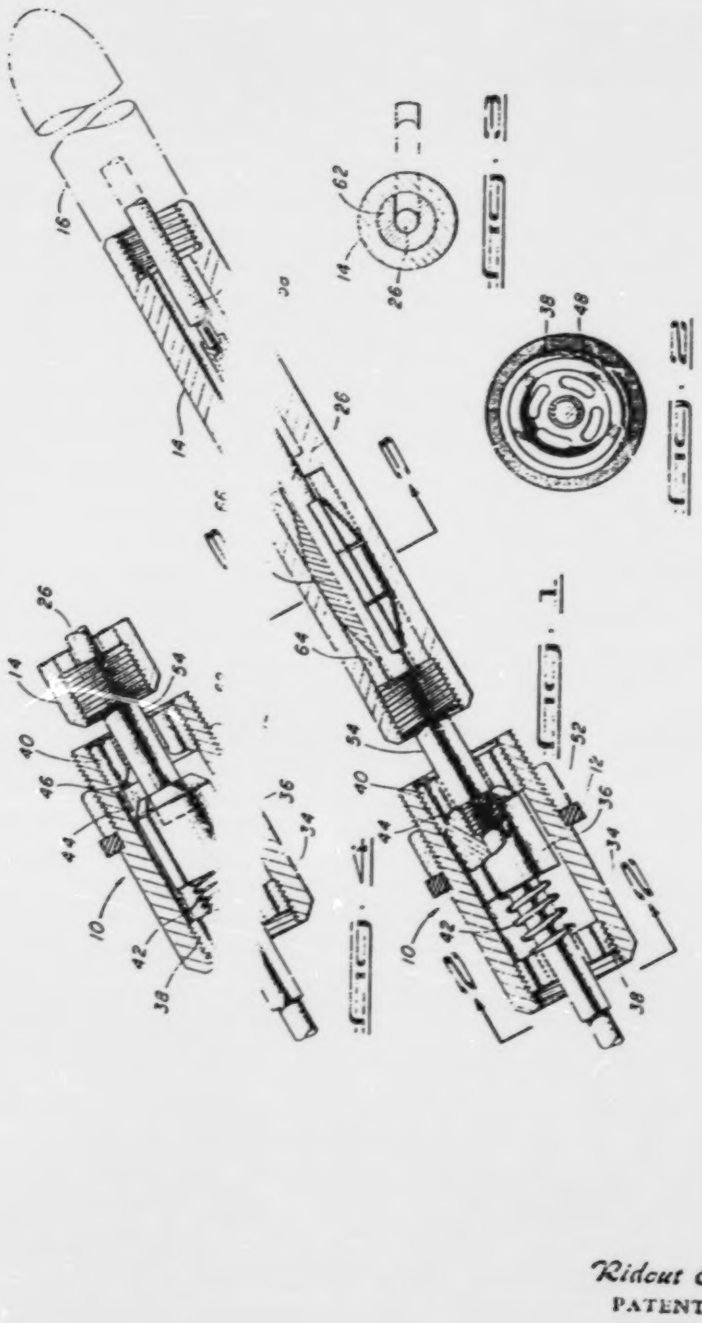
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FIG. 3
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FIG. 2
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FIG. 1
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FIG. 4

Ridout & Maybee
PATENT AGENTS

Figure 5.3.1 - 2 (continued)

1218294

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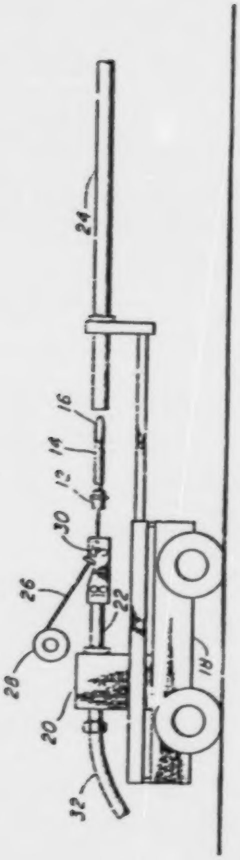
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FIG. 5

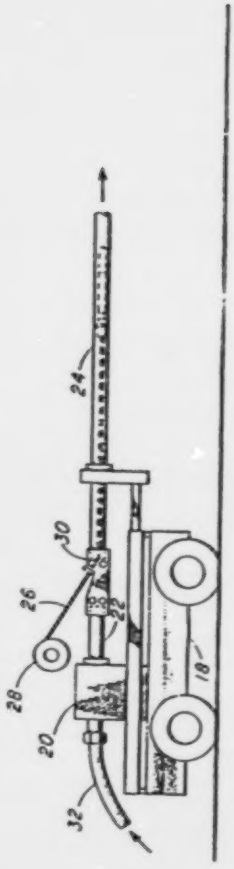
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FIG. 6

Ridout & Maybee
PATENT AGENTS

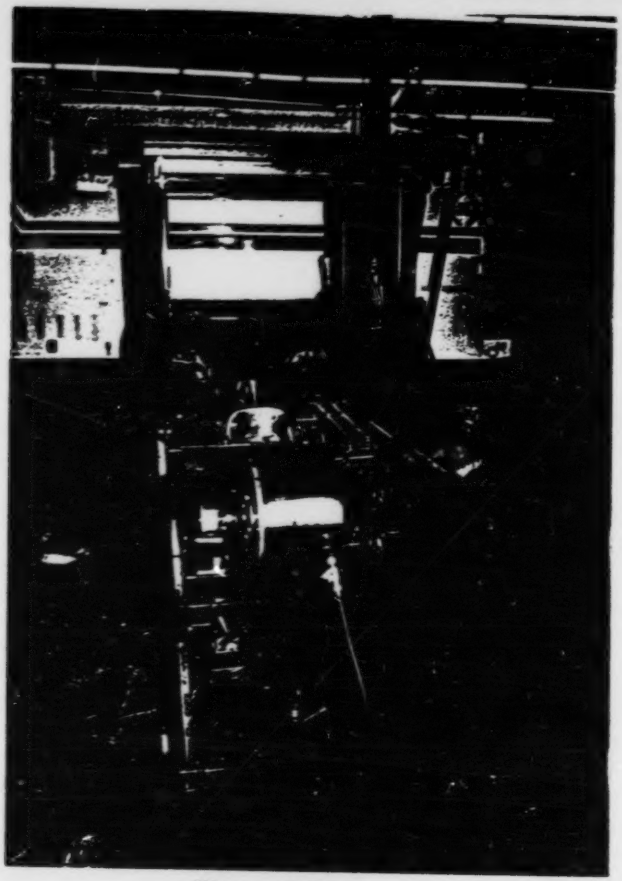

Figure 5.3.1-3
Computalog Borehole Logging System
Developed for Tar Sands Project

AECL, Chalk River, Ontario, have conducted considerable research on inserting probes in boiler tubes using plastic push tubes. The probes are required to go around U-bends within the boiler tubes; however, the typical weight of the probes does not exceed one or two pounds. In other applications, rare earth magnetics are used to attach the probes to the casing with automated pushers. Contacts at AECL recommended using teleflex steel, which was described as a "fancy sewer snake" which could be effective in pushing heavier probes into boreholes. This teleflex cable could be wound on a drum, but was relatively expensive at $3-$4 per foot. AECL also mentioned the use of STEM drives (or storage tubular extendable members, which were similar to tape measures that would roll upon themselves when unrolled from a reel. STEM drives are manufactured by SPAR Aerospace in California but normally only push objects up to 45 meters.

The following is a brief summary of responses from Canadian geophysical equipment manufacturers and contractors.

Crone Geophysics Ltd., Mississauga, Ontario, is primarily involved in EM logging in hard rock mines. Plastic push rods are considered difficult to use and only effective up to 400 feet. The company was very interested in getting a system that can handle distances greater than 400 feet.

Geonics Ltd., Mississauga, Ontario, thought the market for the proposed logging device would be very small, however, the device would be interesting.

IFG Corporation, Brampton, Ontario, indicated there was an interest in Ontario in the ability to log upwards. The company has considered using an end-hole pulley, fixed to the end of the borehole. The probe would then be attached to one end of the pulley and would be drawn inside the hole with measurements taken on the way down. IFG was interested in obtaining a method of logging upwards. IFG also has manufacturing capabilities.

Scintrex Limited, Concord, Ontario, uses push rods for uphole logging, but a continuous logging record is not possible with this system. Scintrex is a manufacturer but would only be interested in pursuing the development of a new system if a readily available market were identified.

Terraplus Incorporated, Richmond Hill, Ontario, are distributors for ABEM, Sweden. ABEM has developed a system to push logging tools upward. It was indicated that the market for upward logging was relatively small, probably only a few units per year required. This company suggested there may be a possibility for a joint venture with ABEM in the development of this equipment.

Urtec Instrument Sales Ltd., Markham, Ontario, markets logging systems internationally and are aware of a need for a system with the capability to log horizontally and upward in both coal and non-coal mining activities. The upward logging technology would be incorporated into their existing geophysical tools. This company wanted to be considered as a potential manufacturer.

Atlas Wireline Services, Calgary, Alberta, were not interested in the proposed logging system.

BPB Wireline Services, Calgary, Alberta, were not aware of any technology for logging boreholes in an upwards direction. They indicated there would be a very limited market; however, a market that could be developed. There was no real interest expressed by this BPB office.

Roke Oil Enterprises, Calgary, Alberta, has carried out overhead borehole logging in underground uranium and potash mines, but have not logged in underground coal mines. Roke Oil has built its own logging equipment since 1977 and manufacturers all components except the logging cable and logging truck. Roke does not manufacture for external sales but rather for their own use only. Roke has used both plastic push rods and a hydraulic method to pump the probe in an above-horizontal hole. Pressure was then released at a controlled rate using a fluid-control valve to give a uniform logging speed. The hydraulic method proved good for diamond drilling down to and including BQ (2.36" bit size).

Schlumberger of Canada, Calgary, Alberta, has almost no experience in coal mine geophysical logging and saw little opportunity for cooperation with our project.

Quantech Consulting Inc., Mississauga, Ontario, frequently used upward logging in hard rock mines where electromagnetic measurements are taken. PVC push rod systems can be used up to 400 feet but are cumbersome and difficult to move around in the mine. The company has developed a prototype pulley system where a pin was planted in the bottom of a borehole with a sleeve and pulley. This system was used in 1,200 meter holes, but there was trouble with twisted cord. The company recommended that a new system designed must be portable and relatively inexpensive and easy to use. There may be a market for uphole logging for electromagnetic logs for base metal exploration. This company had designs for their pulley prototype and hydraulic systems.

Hudson Bay Mining, Flin Flon, Manitoba, developed a hydraulic system for pushing probes in hard rock mines. The boreholes were lined with plastic rod, of smaller diameter than the hole itself, so that water can pass out between the plastic casing and the drilled hole. Hudson Bay Mining has developed a bleed-back valve to enable the probe to be pulled back out of the borehole during logging operations. Their experience with push rods was that the push rods will damage a data transmission cable and are useful only for limited distances. Hudson Bay Mining also used drill strings to push probes into boreholes from 183 - 245 meters and have gone as deep as 914 meters. At this depth, cable tended to break. Steel casing was not used in pulsed electromagnetic logging as logging is carried out in open holes.

According to Lamontange Geophysics, only about 5% or less of the total logging done is in a horizontal or upward position. Push rods are effective up to about 400 feet. Difficulty is encountered pushing probes at an angle greater than 30°.

Canadian FRACMASTER Ltd., Calgary, Alberta, uses coiled tubing for pushing probes horizontally and above the horizon. Figure 5.3.1-4 shows a proposed system to push coiled tubing in holes above the horizontal. This equipment was estimated to cost $50,000 to $60,000 to develop. It consisted of intrinsically safe electric motors connected to hydraulic components and the injector could be adjusted to push the coiled tubing at any angle.

5.3.1.2 United States

United States Patent No. 4,495,992, dated January 29, 1985, entitled Hydraulic Logging Technique for Inverted Oil Wells assigned to Tara Systems Incorporated, Golden, Colorado, provides a hydraulic technique for logging well holes particularly in oil mining environments where the well holes extend upwardly from mining drifts. In the technique, the logging tool is initially positioned within the well hole in a fluid-type, sealing engagement with the well hole. The tool is connected by a flexible cable to conventional logging instruments located in the drift and to raise the tool, fluid under pressure is supplied below the tool within the well hole. Once raised to the desired height within the well hole, the cable is drawn downwardly raising the pressure in the fluid below the tool to a second pressure. Through a disclosed arrangement, including a back pressure regulator, the pressure below the tool is maintained at the second pressure as the cable continues to be drawn downwardly. The logging tool is preferably operated as the tool is being lowered and the steady back pressure serves to provide a constant force against the downward withdrawal of the cable and tool so that the travel rate of the tool is relatively uniform. Other disclosed details of the invention include procedures and apparatus for initially positioning the tool within the well hole and details of a fluid circuit which can be used to both raise and lower the tool. Figure 5.3.1-5 shows the hydraulic logging technique for inverter oil wells.

Figure 5.3.1-4
Canadian Fracmaster Coiled
Tubing Injector System

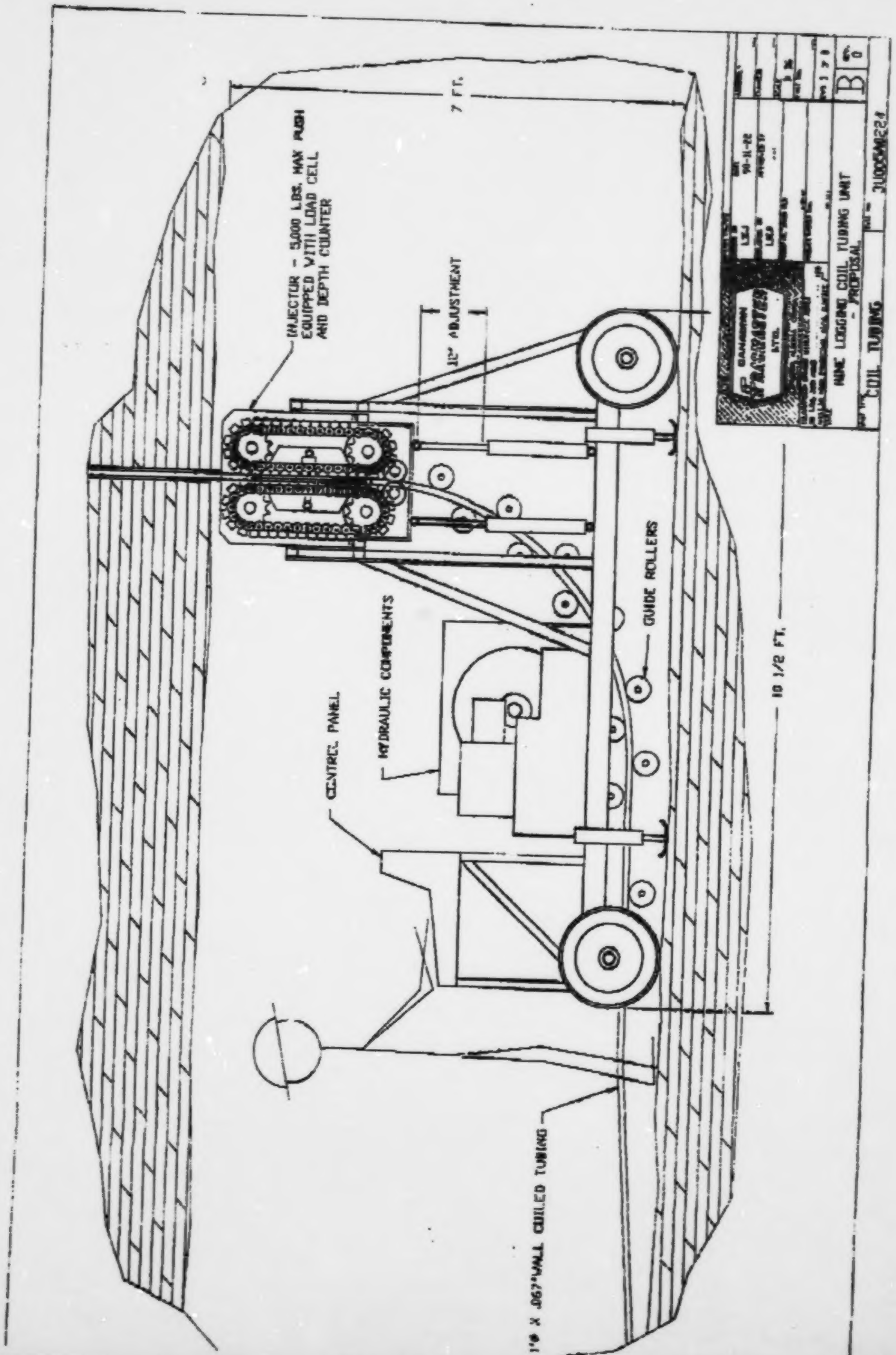
7 FT.
INJECTOR - 5,000 LBS. MAX PUSH
EQUIPPED WITH LOAD CELL
AND DEPTH COUNTER
12" ADJUSTMENT
GUIDE ROLLERS
HYDRAULIC COMPONENTS
CONTROL PANEL
10 1/2 FT.
1" X .067" WALL COILED TUBING
CANADIAN FRACMASTER LTD.
90-11-22
MINE LOGGING COIL TUBING UNIT
- PROPOSAL
COIL TUBING
JU005M0224
B

Figure 5.3.1-5
Hydraulic Logging Technique for Inverted Oil Wells
US Patent 4,495,992, Issued 24 Jan 85

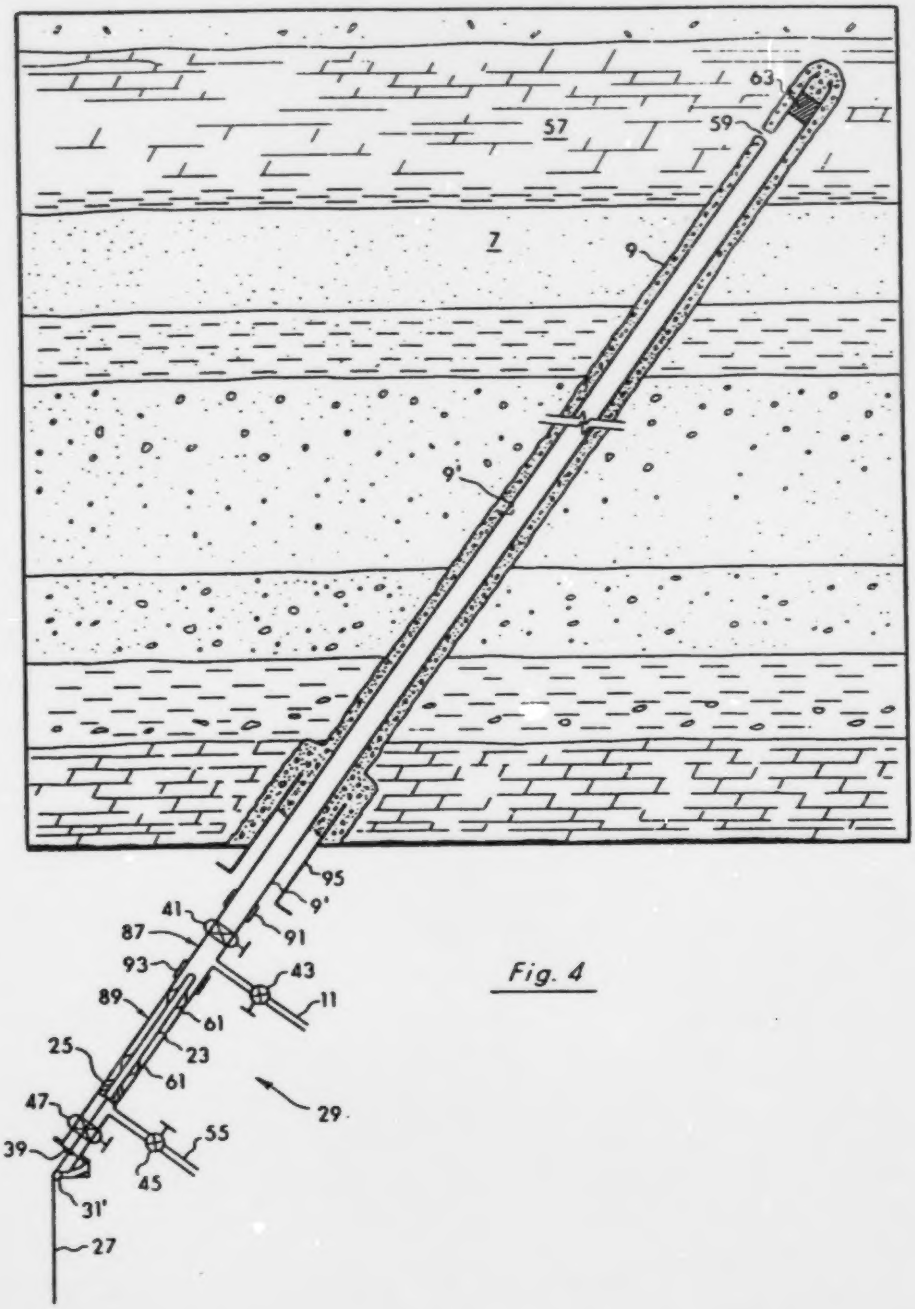
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Fig. 4

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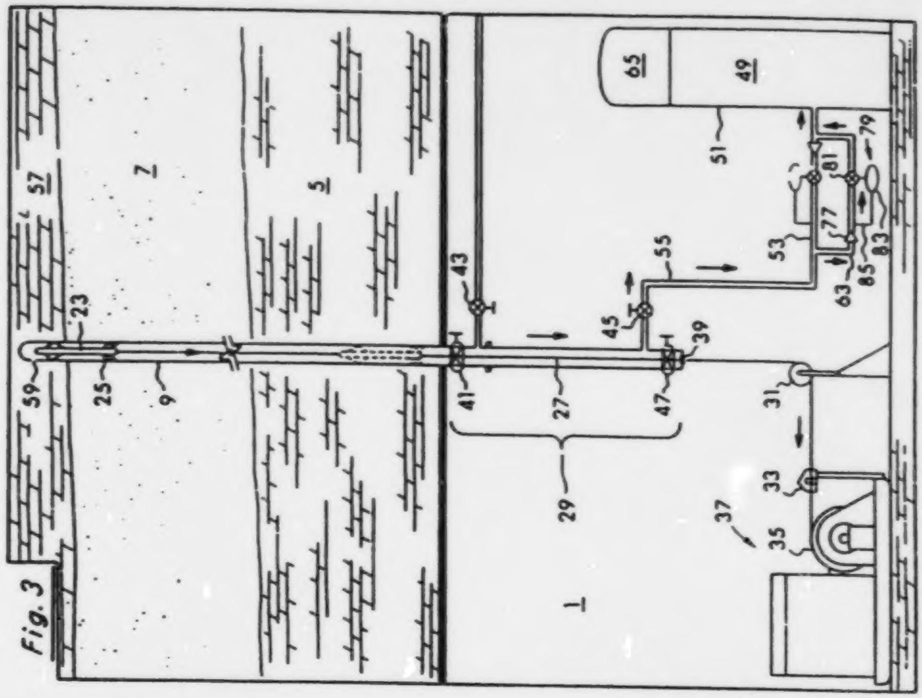
Fig. 3

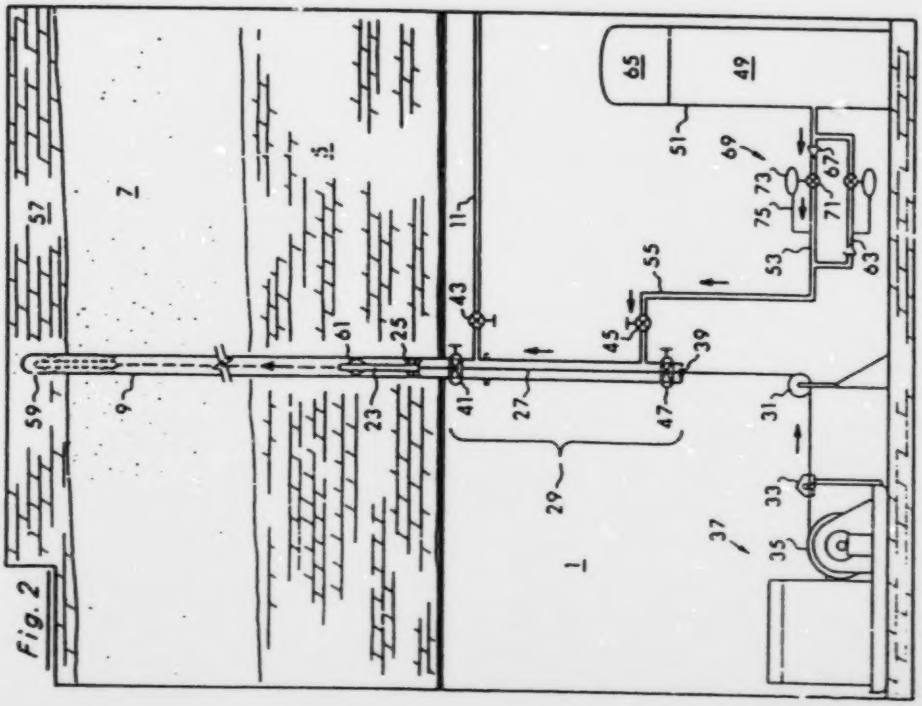
Fig. 2
75, 73

A number of U.S. geophysical contractors and equipment manufacturers responded to our survey.

EG&G Geometrics, Sunnyvale, California, were interested in the project if there were a demonstrated market interest. This company has a large installed base of borehole coal analysis system worldwide and there may well be foreign market opportunities.

Neltronic Instrument Corp., Houston, Texas, were only willing to comment on the project on a fee-basis.

Owl Technical, Longmount, Colorado, have developed a line of push rods and were not interested in developing a new system.

Century Geophysical Corporation, Tulsa, Oklahoma, indicated that the company did about 60% of the mineral logging done in the U.S. They receive requests for upward logging of coal mines about once every two years. Push rods are used to 91.4 meters. There may be an opportunity in deep coal or uranium mines but the market would be very small.

Schlumberger Well Services, Houston, Texas, indicated that they log horizontally by putting tools on the end of a drill pipe. Coil tubing may also be used to push probes and has the advantage of being wound on a drum. Dowell Schlumberger manufacturers this coil tubing. The oil industry normally drills 6-1/4 to 12-3/4 inch holes (158.75 to 323.85 mm).

Colog Incorporated, Golden, Colorado, has done uphole logging using push rods and pumping the logging tool up the hole with water pressure. Another approach used in the past is a working memory drive in a Dewer flask on the end of the drill rod. This company has a digital acquisition system for slimhole logging. Colog was willing to work in the development of the proposed equipment; however, the company does not manufacture equipment.

5.3.2 Europe

During the literature search, a patent was identified which was awarded to the Institute Francais du Petrole, France, which had the ability to log in an upwards direction. Figure 5.3.2-1 shows a diagram of the equipment.

Figure 5.3.2-1
French Patent for Upward Logging Equip
EP#87400639.8, Dated 23 03 87

(19) Europ
European Patent Office
Office européen des brevets

(11) Numéro de publication: **0 242 256**
A1

(12) DEMANDE DE BREVET EUROPEEN

(21) Numéro de dépôt: **87400639.8**

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E 21 B 47/00, E 21 B 19/22,
E 21 B 21/00, E 21 B 33/068

(30) Priorité: **04.04.86 FR 8604960**

(43) Date de publication de la demande:
21.10.87 Bulletin 87/43

(84) Etats contractants désignés: **DE GB IT NL**

(71) Demandeur: **INSTITUT FRANCAIS DU PETROLE**
4, Avenue de Bois-Préau
F-92502 Rueil-Malmaison (FR)

(72) Inventeur: **Wittrisch, Christian**
24, rue George Sand
F-92500 Rueil-Malmaison (FR)

(74) Mandataire: **Kermarrec, Michelle et al**
Institut Français du Pétrole 4, avenue de Bois-Préau
F-92502 Rueil Malmaison (FR)

(54) Procédé et dispositif pour effectuer des mesures caractérisant des formations géologiques, dans un forage horizontal réalisé depuis une voie souterraine.

(57) Il comporte essentiellement une sonde (11) contenant des instruments de mesure, adaptée à être introduite et poussée dans le forage à l'extrémité d'un élément allongé tel qu'un tube semi-rigide (2) qui est déroulé d'un touret de stockage (1), redressé et déplacé linéairement par des moyens d'entraînement (4). Le tube passe au travers d'un élément d'étanchéité (12) disposé à l'orifice du forage. Il contient un câble de transmission (22) pour relier la sonde à un ensemble de commande et d'enregistrement (24) et il communique par un collecteur hydraulique et électrique tournant avec un système de pompage (19) destiné à remplir de fluide le trou foré avant d'effectuer les mesures.

Application à la reconnaissance des terrains en avant du front de taille sur les chantiers de percement de tunnels ou analogues.

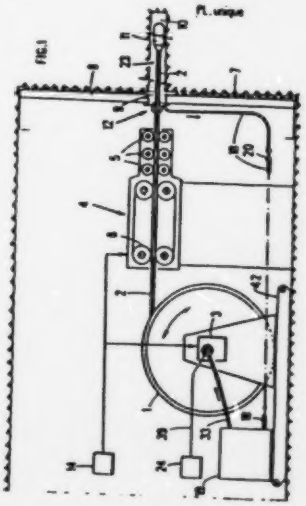

FIG.1

Bundesdruckerei Berlin

FIG.1

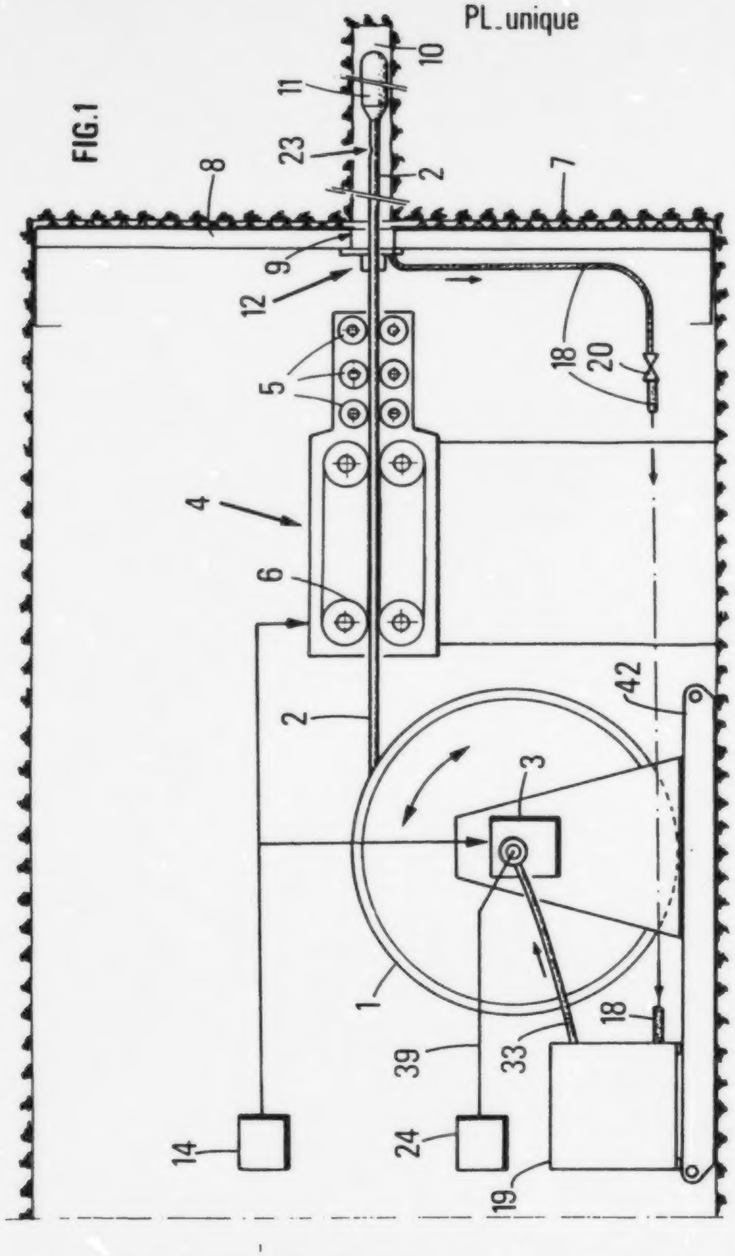
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FIG.3

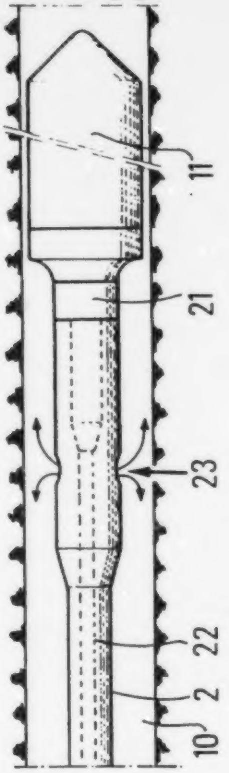
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FIG.2

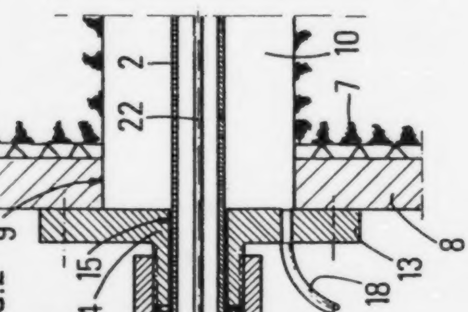
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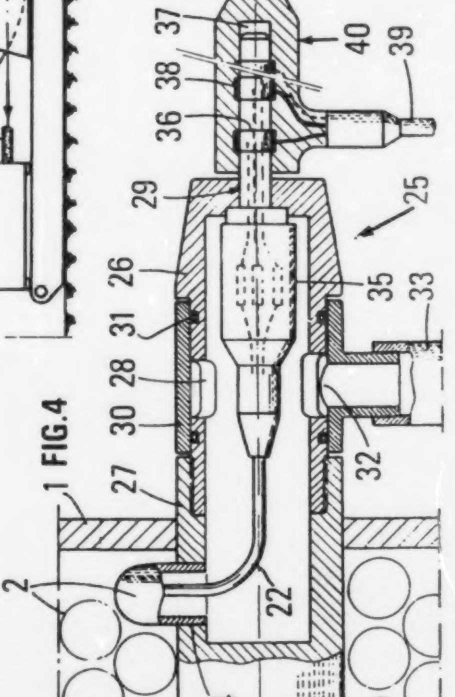
FIG.4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The British Coal Corporation makes extensive use of guided long-hole drilling to help in the mine planning process in identifying anomalies such as faults, washouts, etc. Such information allows coal faces to be laid out so that panels of coal can be planned with greater confidence and that face stopping geological problems will not be encountered. Other applications of guided long-hole drilling include the remote placing of seismic sources and geophones, strata identification, underground coal gasification, the location of old workings as an aid in rescue operations, drilling cross-measures in advance of roadways, target drilling for drainage purposes in the installation of services. The British Coal Corporation drills horizontal boreholes up to distances of 1,000 meters. The SEI MK2 Probe is used as the guided long-hole drilling probe to ensure continuity within the coal seam. British Coal Corporation has a specialist team of three people for doing all the horizontal logging required in England. This specialist team is available for work outside the British Coal Corporation only on a time availability basis; however, BCC generally finds it difficult to supply and support the probe system outside their own operations. BCC will offer advice and training on the application of the probe system. The guided long-hole drilling probe is manufactured by SEI Ltd., Haywood, Lankeshire, England, at a system cost of £41,000 including one magnetometer probe, one battery pack and one control unit. The probe can be used within standard NQ/NT size (2.75" O.D., 2.375" I.D.) drill strings. The probe is pumped down the NQ/NT rods of the drill string, with probe retraction via a wireline and winch assembly. Additional information on guided long-hole drilling and the SEI MK2 Probe are contained in Appendix A5.1. This equipment is not as flexible as that being developed for Cape Breton Development Corporation as it does not take continuous logs, and the sensors are used to prove continuity and maintain the drill hole within the coal seam. Contacts with the British Coal Corporation, Geotechnical Services, indicate that British Coal rent small, portable, underground logging systems from BPB Instruments. All logging done in England is done by contract; 90% by BPB, the rest from Robertson Geologging Ltd. The BCC uses a pulley system to insert and retrieve probes, normally in a horizontal position. Attempts to pump probes upwards in the past were not successful, although some success was achieved with pumping probes along horizontal boreholes. At least 95% of the logging undertaken by BCC is downhole logging and there is a small requirement for logging upwards. Measurement while drilling techniques are also used by BCC.

Robertson Geologging Ltd., North Wales, UK, undertook a feasibility study approximately three years ago, at the request of British Coal Corporation into the development of an intrinsically-safe logger. The conclusion was that such a system, together with a limited range of downhole tools, could be produced by adaption of RG's current technology. This tool range included gamma-gamma (density), neutron and natural gamma. Tools such as a caliper (borehole diameter) which requires downhole motors appeared more difficult and such measurements might have to be achieved by unconventional techniques. British Coal decided not to pursue the development of a system. RG did not continue with the development of the system as the market appeared limited. In addition, the need to satisfy the different safety requirements and certification procedures required by individual countries appeared to be a "potential minefield." Although RG have experience in horizontal logging, this has been confined to clients where access could be obtained at each end of the hole to allow a draw rope to be pulled through. It is thought that coiled tubing may be useful in our situation. RG indicated that the system developed by DMT of Germany, probably is the best in-mine logging unit on the market now and it appears to cover the market well. RG's only other inquiry for intrinsically-safe loggers came from Poland; however, this interest appears to no longer exist.

Reflex Instrument AB, Sweden, has developed the Reflex Minibor^{TM} instrument to investigate deviations in short boreholes. A typical survey arrangement comprises a 0.8 meter long probe which is inserted into the hole on light-weight aluminum push rods. A tough, multi-core cable connects the probe to a portable battery-powered computer (any MS-DOS based portable can be used in connection with the Minibor^{TM} system). The probe's accelerometer system sends dip and direction information to the computer as it is being pushed deeper into the hole. The data is processed while the survey is in progress and shown graphically on the computer screen. Figure 5.3.2-2 shows the application of the Reflex Minibor^{TM} instrument and also technical specifications of the equipment. Once again, this equipment is for measuring deviations in boreholes, and does not include nuclear probes as does the equipment proposed for the Cape Breton Development Corporation.

Another Swedish company, ABEM AB, has technology and experience in logging upward but not to the distance of 300 meters. The equipment designed by ABEM AB is custom designed and therefore printed material and specifications are not available. Thus far, ABEM AB-designed equipment can measure boreholes of approximately 50 meters in length with a direction of 75° upwards. In horizontal boreholes, the equipment can be used to measure several hundred meters deep.

The system most similar to the borehole logging system being developed for the Cape Breton Development Corporation was that produced by DMT of Germany. The borehole logging system, called INLOG,^{TM} was developed from the British Plasterboard Instruments (BPB) equipment used by the British Coal Corporation. Funding to develop the INLOG^{TM} system was provided by the North Rhine-Westphalia Land, Bergbau AG, Westfalen, and developed by the WESTFALISCHE BERGGEWERKSCHAFTSKASSE INSTITUTE OF GEOPHYSICS. One of the INLOG^{TM} models, the GBM 77 Borehole Measurement Equipment, can carry out logging on boreholes up to 550 meters deep. INLOG^{TM} is fully explosion-proof, conforming to European regulations. The probe includes natural gamma ray and gamma-gamma (density) analysis. A neutron-neutron probe would need further development. INLOG^{TM} is routinely used in the German coal industry to log drill holes in every direction, including vertically upwards. DMT would be interested in selling an INLOG^{TM} system to Canada but would not be interested in the manufacture or marketing of any other equipment that would be competitive to INLOG^{TM}. Currently there are three INLOG^{TM} systems in operation in Germany, but there are no systems in use outside of Germany. The INLOG^{TM} system uses pulleys with two winch systems to enable measurements to be taken in any direction. Additional information on the WBK INLOG^{TM} system is contained in Appendix A5.2. Daily costs to lease the INLOG^{TM} system are approximately $1,589, including the operator. This would equate to a system cost of roughly $250,000 (if normal industry consulting rates are used). The INLOG^{TM} system would have to be re-designed for the Cape Breton Development Corporation coal mines, as the existing probes are too large a diameter for BQ drill rods.

Sondex Well Logging Instrumentation, Workingham, Berks., UK, indicated that push rods or pumping the probe up the borehole with water were used when upward logging was required. In either case, it was not easy to obtain a smooth log and the best method may be to take point readings at 10 centimeter intervals and construct a log by plotting these. No interest was expressed in developing new equipment.

Figure 5.3.2-2
Reflex Instrument AB – Reflex
Minibor Borehole Deviation System

How crooked are your short holes?

Now there is a way to find out – fast, accurate and simple with the Reflex Minibor system.

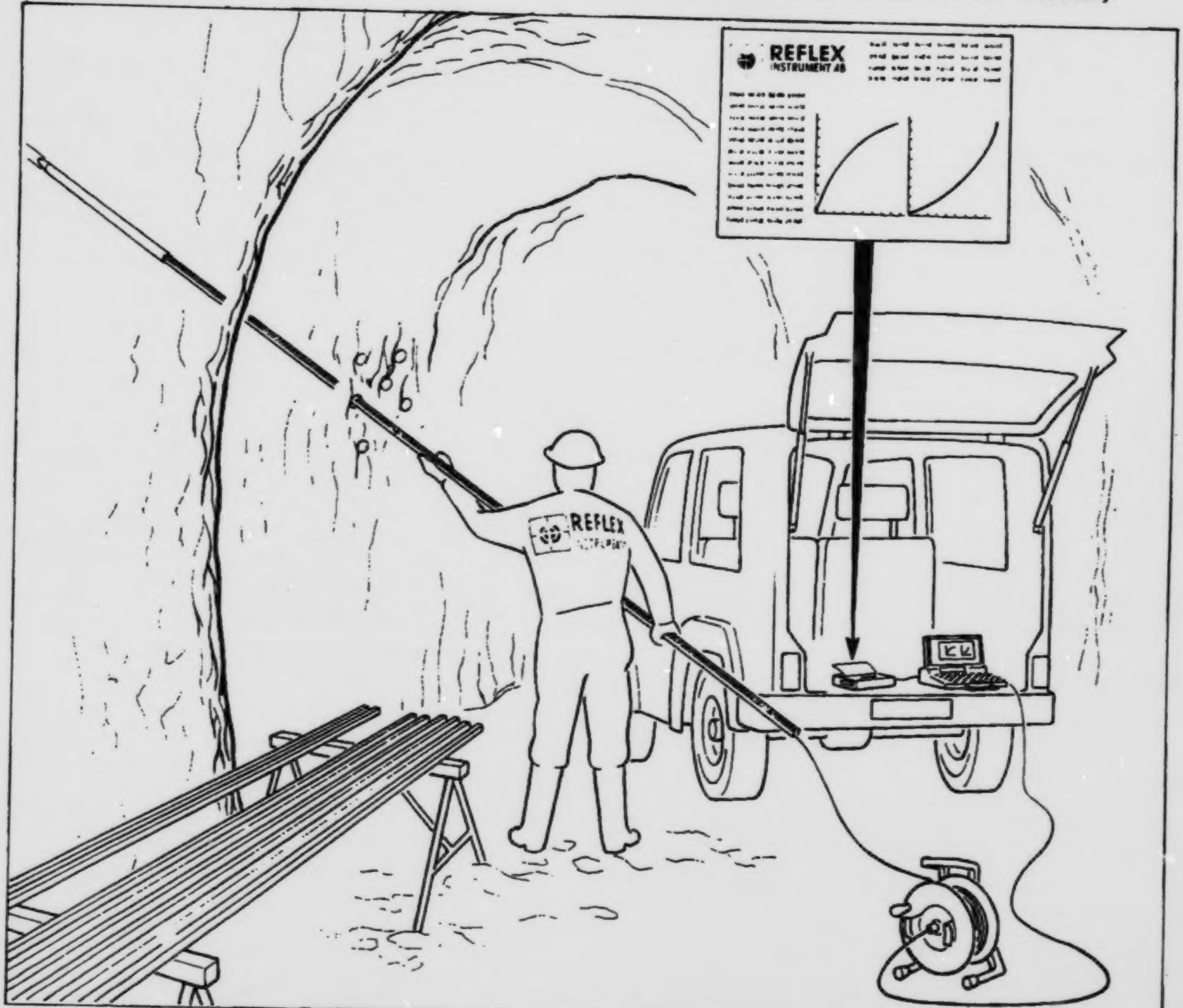
Drillholes for blasting, grouting, freezing, drainage, inspection or other purposes deviate from planned targets for a number of reasons. The major contributing factors are

- geological conditions
- inadequate collaring
- drilling equipment
- drilling technique

Dip and direction deviations of up to several meters in bench drilling or longhole mining are not uncommon.

Deviations of this magnitude, if unrevealed, can lead to costly and unpleasant surprises, such as unsuccessful blasting or even blasting accidents. Short hole deviation surveys will help the driller add additional holes at correct positions, if needed.

In engineering projects such as grouting programs on dam sites or when freezing techniques are used for stability, exact knowledge of hole positions is also necessary.



The Reflex Minibor Instrument investigates short holes quicker and more accurate than any previously available instrument.

A typical survey arrangement comprises a 0,8 m long probe which is inserted into the hole on light weight aluminium push rods. A tough multicore cable connects the probe to a portable battery-powered computer. (Any MS-DOS-based

The probe's accelerometer system sends dip and direction information to the computer as it is beeing pushed deeper into the hole. The data is processed while the survey is in progress, and shown graphically on the computer screen.

Upon completion, a full report as well as graphic hole presentations are printed on a portable printer.

Figure 5.3.2 - 2 (continued)

REFLEX MINIBOR

Technical specifications

Power pack with built in charger for 110/220V, 50/60 Hz	8 rechargeable NiCd F-cells batteries
Battery life	Approximately 12 hours
Ambient temperature	–40 to + 65°C
Shock resistance	100 G for 11 msec
Measuring accuracy	0,1% of measured length
Temperature drift	0,005% per degree C
Zero error	0,03%
Measurement range (dip)	–90 to –30 and +30 to +90 degrees
Measurement range (dir)	0 to 360 degrees

Standard system includes

Minibor probe, length 0,8 m, diameter 42,5 mm
Cable winch with 50 m cable
Rodholder, (lifter)
Battery pack with built in charger
Minibor software on 3,5" or 5 1/4" disks (MS-DOS 3.2)
Instruction manual
25 2m long push rods
2 adjustable oversize collars

Recommended computer

Toshiba 1100+ or compatible

Recommended printer

Epson Mx80, IBM or compatible

Recommended plotter

HP 7475 A or compatible

Gross weight standard system	c:a 100 Kg
Shipping details	2 boxes 2008x415x135 mm

Product development is continuous. Get up to date technical and commercial details from

REFLEX
INSTRUMENT AB

Postal address	Visiting address	Telephone	Fax:	Telex:
Box 116 S-186 22 Vallentuna Sweden	Jan Fridegårds väg 19 Vallentuna	+46 762 734 10	+46 762 734 20	12021 Reflex S

REFLEX distributor

Norex AS
PO Box 70
N-8230 Sulitjelma
Norway
Phone: +47 81 40 700
Fax: +47 81 40 305

BPB Instruments Ltd., Loughborough, Leicestershire, UK, indicated they do not have any equipment for upward borehole logging although this is questioned based on the comments from the British Coal Corporation.

5.3.3 Other Countries

Stratalog PTY Ltd., Brisbane, Australia, was the only other company indicating experience with upward borehole logging. Over the years, Stratalog has assisted a number of companies and government departments with supply of equipment for horizontal and vertical logging. All these activities have generally been done on a low-budget, one-off requirement. The company's investigations to try to develop a good, marketable system have been curtailed by lack of finance and lack of interest from potential users to support such a project. They have undertaken detailed investigation into a winching system and have estimated development cost to be in the order of US$50,000 with a subsequent selling price of approximately US$25,000. Stratalog normally uses push rods for horizontal and upward logging for special applications. Stratalog expressed an interest in cooperating in the development of the proposed system; however, as of December, 1990, Stratalog has gone out of business.

The literature search identified some core logging instrumentation developed by the Australian government. The C.S.I.R.O. Division of Mineral Physics, Port Melbourne, Victoria, developed a bolt hole probe known as Stratasnoop^{TM}, which measures the depth of the mudstone and delineates the boundary between mudstones and sandstone. The device consists of CsI(Na) gamma-ray detector and associated electronic equipment. The Stratasnoop^{TM} probe is 25 mm in diameter and is inserted into boreholes using fibreglass push rods to a distance of 1.8 metres. The StratasnoopTM is an easily portable unit which uses natural gamma, gamma-gamma (density), neutron-gamma and neutron-neutron probes. The probe is powered by lead-acid gel cells that provide 12 hours of operation. The rate meter, power cells and the battery charger are enclosed in a leather case that hangs from the operator's neck.

Stratasnoop^{TM} is used to determine the placement of mine support bolts. The device is licensed to ETP Pty. Ltd., Sydney, NSW. Information on Stratasnoop^{TM} is contained in Appendix A5.3.

5.4 Market for the Proposed Borehole Logging System

5.4.1 North America

Attempts to find statistical information on the amount of borehole logging undertaken in North America proved fruitless. A few geophysical contractors guessed that only about 5% of logging was conducted underground. Underground logging is a small, specialized market and appears to be covered by existing equipment and technology.

The survey of geophysical contractors and equipment manufacturers identified a number of companies interested in our proposed borehole logging equipment. Some even expressed interest in joint development efforts, assuming funding could be found.

None could identify a specific market for borehole logging, and would only be interested if markets were identified.

The survey of coal mines in Canada and the U.S.A. identified interest in underground logging in Canada only at Cape Breton Development Corporation and in the U.S.A. at Consolidated Coal, Illinois.

Consolidated Coal, Illinois, is one of the larger coal operations in the U.S. and has its own Research and Development Department. This company was interested in the in-mine logging unit for exploring ahead of the mine face through horizontal holes. Information required included whether or not the seam was continuous, the thickness of the seam, any fractures present, determination of hardness and the density of the seam. In addition, this company has a coal seam under a lake, where currently drilling is conducted at great expense from a floating barge.

The U.S. Bureau of Mines appears to have focused its research on Measurement While Drilling techniques as a method to identify coal seams and their contents rather than borehole logging and other technologies.

Some geophysical contractors indicated that the proposed borehole logging system may be useful in uranium mines though, currently, that industry was in decline.

5.4.2 Europe

The problems of multi-seam mining and in-mine logging appear to be better addressed in Europe. Both the British Coal Corporation and DMT of Germany have equipment for logging horizontally and above the horizon from within a mine. We were unable to quantify the market, although it is small and specialized. DMT of Germany received government and industry funding to develop the INLOG™ system currently used only in German mines. Only three of these units are being used within the German coal industry. No INLOG™ systems are operating outside of Germany, although DMT expressed an interest in selling or leasing a unit. This would indicate that the market in Europe was very limited.

The British Coal Corporation has a team of three men who do all the horizontal borehole logging required in England. BCC offers to assist mines outside of England; however, they currently do not do work outside the country.

Robertson Geological, Wales, have had enquiries from Poland concerning horizontal and upward logging, but these have disappeared, thus a Polish product may have been developed or technology from another country (probably Germany or USSR) is being used.

We were unable to obtain a response from contacts in USSR, Poland or France, so the state of the technology or market in these areas is not known. Robertson Geological did not think there was much of an opportunity. In the early 1980's, while visiting Germany, it was indicated that French underground logging requirements were satisfied by German equipment.

5.4.3 Other Countries

The only other organization that expressed interest in the proposed equipment was the Nigerian Coal Corporation and the Geological Survey of Nigeria. These organizations currently use core drilling, core recovery and logging from the surface to determine seam rhythm, seam depth, thickness and the lithostratigraphy. An application for the proposed system was seen to determine coal seam depth, thickness, coal quality and borehole stratigraphy. The Nigerian Coal Corporation drilled and logged ten boreholes this year.

5.5 Conclusion

1. The market analysis was unable to accurately quantify the potential for the proposed in-mine geophysical borehole logging system.

2. The market for in-mine logging appears to be very small, estimated by some to be less than 5% of all borehole logging in coal mines. A number of existing systems and technologies were identified that are used for logging horizontally and above the horizon. In many cases, fairly simple and inexpensive methods were used such as push rods, pulley systems and hydraulic systems to log in an elevated boreholes, using probes and data acquisition systems currently on the market.

3. The new system would have to prove it could do the job cheaper, easier or better than existing systems. The proposed system appears more convenient to use than push rods, but the cost is unknown. The current market for the proposed system is estimated to be 3 to 5 units.

4. With the highly specialized and small market identified, it is unlikely an industrial partner will easily be found. However, it is likely that a market could be developed over time through demonstration and use, particularly in North America.

5. A competitive product would have difficulty developing existing products in Europe. European systems received considerable government and industry support in their development. Given the close relationships between the mining industries and government, there will be reluctance to adopt a foreign system.

6. The German INLOG^{TM} system appears to be the current "state-of-the-art" system. However, the probe size is too large to fit into NQ/BQ sized drill strings used by the Cape Breton Development Corporation. In addition, INLOG^{TM} performs only two of the three functions specified by the Cape Breton Development Corporation. The practicality or cost to modify the INLOG^{TM} system was not determined.

7. Apart from the market for the complete geophysical logging system, an additional market may be created for the probe inserting/winch mechanism alone. Universal fittings would be required to adapt to existing geophysical probes and data acquisition systems. Potential applications include coal, hard rock mines, oils wells and video inspection services.

6 PATENTS

As discussed in section 3.2, there are four methods generally used for actively pushing a geophysical probe into a borehole that is horizontal or above the horizontal. These are:

1. Push Rods, Wire or Tubing
2. Fluid Pressure Behind Probe
3. Use of Drill String as Pusher
4. Use of a Hole-end Pulley.

A number of patents have been identified which describe systems which use one or more of the above systems. Some of these have been mentioned in section 3. Below are listed the patents with a number indicating which of the identified above methods it describes.

PATENT#	TITLE	DATE	INVENTORS	PROBE INSERTION METHOD	REFERENCES
1,188,361	Method of and Apparatus for Mining Analysis	85 06 04	LeBlanc Smith, Guy; Howard, Derik, South Africa	1 & 2	
1,218,294	Pump Down Tool and Check Valve	87 02 24	Mason, Charles E., U.S.A.	2	U.S. Pat.# 4,295,536
4,495,992	Hydraulic Logging Technique for Inverted Oil Wells	85 01 29	Hutchins, John S., Littleton; DeFours, Mervyn A., Golden, Colorado	2	U.S. Pat. Documents 1,870,869 3,401,749 3,696,332 4,082,144 4,339,006 4,349,072
0,242,256 A1	Procédé et dispositif pour effectuer des mesures caractérisant des formations géologiques, dans un forage horizontal réalisé depuis une voie souterraine.	87 03 23	Wittrisch, Christian, F-92500 Ruell Malmaison, FR	2	US-A-4 498 532 (MASON) US-A-3 777 827 (THIERY) US-A-3 285 629 (CULLEN et al.)

It appears that if the building of a new system is contemplated using one of the listed methods, then some consideration will have to be given to the determination of what responsibilities are owed to the holders of these patents.

The only method not seen anywhere to date is that of a motorized probe which can crawl into the hole. However, this method has been disqualified for this project because of its perceived expense and technical risk.

7 SYSTEM COSTING AND SCHEDULE

As outlined in Section 3.0 a product development project can have the following phases:

	Project Phase	Output
I	Conceptual Design	Concept
II	Preliminary Design	Model
III	Detailed Design	Prototype
IV	First Production	Finished Product

In projects involving the development of a product with a sizeable market, these phases can be distinct and well defined; but for products with limited markets a protracted development program cannot be justified. The results of the Market Survey indicate that the In Mine Borehole Logger is in the latter category, so a modified approach is necessary. We envisage this approach to take the following form:

	Project Phase	Output
I	Conceptual Design	Concept
II	Design and Fabrication	First Unit
III	Design Enhancements	Production Units

The conceptual design culminating in this report, defines the concept. The design and fabrication phase is a combination of the previous model's preliminary design and detailed design phases. It results in the production of a functional "first unit" which can be operated by the end user. After a period of use a third phase called design enhancements is carried out which provides an opportunity for a design interaction and results in modifications to the first unit and the fabrication of production units to meet demand or an upgrade of the initial unit for improved operation.

7.1 Cost Analysis - General

The cost analysis is in the form of a spreadsheet (Section 7.3) and mainly addresses the costs involved in the "design and fabrication" phase. It also makes a budgetary prediction of costs for the "design enhancements" phase which results in an estimated unit price for production units.

7.1.1 Cost Analysis - Design and Fabrication

The analysis is set up to show costs separately for the following assemblies and activities.

1. Probe Assembly - decentralized
2. Probe Assembly - centralized
3. Geophysical Cable Assembly
4. Winch Assembly
5. Electronics Module
6. Seal Tee Assembly

7. Water Manifold Assembly

8. Accessories

9. System Test and Evaluation

10. Manuals

11. Software

Under "total system" the total design and development cost and the total fabrication cost is shown. All labour is costed at overhead rates and contingencies are shown for each cost category in each assembly/activity. The total first unit cost therefore is the break even cost of the design and fabrication phase. A separate entry shows the estimated break even cost of spares.

7.1.2 Cost Analysis - Design Enhancements

This part of the analysis works up a selling price for production units based on sales of 6. The following explains the headings which appear on the spreadsheet.

Total Design and Development Costs:

This represents the non-recurring costs for this phase and is estimated as 50% of the design and development costs of the design and fabrication phase.

Total Fabrication Cost Based on 6 Units:

This was calculated by taking 90% of the fabrication material cost and 75% of the fabrication labour costs without contingencies.

Unit Fabrication Cost Including First Unit and Design and Development:

This is one sixth of the total fabrication cost based on 6 units with contingency plus one sixth of the total first unit cost plus one sixth of the phase III design and development costs.

Unit Price with 30% Margin:

This is a suggested selling price of production units without spares based on the following equation:

$$\text{Selling Price} = \frac{\text{Unit Fabrication Cost Including First Unit + Design and Development}}{(1 - 0.3)}$$

7.2 Schedule

Based on past experience with product development projects of similar equipment the following time frame is envisaged:

	Project Phase	Duration
II	Design & Fabrication	10 Months
III	Design Enhancements	4 Months

7.3 Cost Analysis - Spreadsheet

IN-MINE BOREHOLE LOGGER COST ESTIMATE

DATE: JAN 16/91

FILE NAME: LOGGERCOST.w20

PROBE ASSEMBLY-DECENTRALIZED DWG B-SK-0897

ALL COSTS ARE PER UNIT BASED ON MAKING 1 UNIT

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG		DRAFTING		ENGINEER		TECHNOLOGIST		TECHNICIAN	
						(HRS)	$	(HRS)	$	(HRS)	$	(HRS)	$	(HRS)	$
1	1	DM	DENSITY PROBE	GAMMA-GAMMA; COLLIMATED; NELTRONIC INSTR	5835.1		0.00								
2	1	9380-001	DENSITY SOURCE	CESIUM 137; 150 MILLICURRIE; COMPROBE	4749.5										
3	1	4000-057	STORAGE SHIELD ASSY	FOR DENSITY SRCE; SLEEVE TYPE; COMPROBE	542.8										
4	1	4 PI SPECIAL	DENSITY CALIBRATOR	1.25" OD ALUMINUM; COMPROBE	1458.775										
5	1	4000-021	DENSITY CALIBRATOR	1.25" OD ACRYLIC; COMPROBE	814.2										
6	1	4000-020	DENSITY CALIBRATOR	1.25" OD MAGNESIUM; COMPROBE	1458.775										
7	1	---	FORWARD SUPPORT ASSY-BQ	BODY+DECENTRALIZING COMPONENTS, 4" LG	20	4.00	156.00	8.00	312.00	16.00	1000.00				
8	1	---	FORWARD SUPPORT ASSY-NQ	BODY+DECENTRALIZING COMPONENTS, 4" LG	20	4.00	156.00	1.00	39.00	2.00	125.00				
9	1	---	FORWARD SUPPORT ASSY-HQ	BODY+DECENTRALIZING COMPONENTS, 4" LG	20	4.00	156.00	1.00	39.00	2.00	125.00				
10	1	---	REAR SUPPORT ASSY-BQ	BODY+DECTRLZG & SEALG COMPONENTS, 8" LG	50	6.00	234.00	6.00	234.00	12.00	750.00				
11	1	---	REAR SUPPORT ASSY-NQ	BODY+DECTRLZG & SEALG COMPONENTS, 8" LG	50	6.00	234.00	1.00	39.00	2.00	125.00				
12	1	---	REAR SUPPORT ASSY-HQ	BODY+DECTRLZG & SEALG COMPONENTS, 8" LG	50	6.00	234.00	1.00	39.00	2.00	125.00				
			ASSEMBLY:											8	216
				TOTALS:	15069.15	30.00	1170.00	18.00	702.00	36.00	2250.00	0.00	0.00	8.00	216.00
			TEST & EVALUATION-PROBE:	DETERMINE IF PROBE IS INTRINSICALLY SAFE MAKE MODIFICATIONS AS REQUIRED OBTAIN CERTIFICATION	200.00	24.00	936.00	16.00	624.00	32.00	2000.00	32	1248	32	864
			TEST & EVALUATION-SEALING AND SUPPORT:	DO SEAL AND SUPPORT TESTS IN 1 LENGTH OF DRILL PIPE. MAKE MODS AS REQUIRED.	586.85	16	624.00	8.00	312.00	24.00	1500.00	0	0	24	648

RECURRING COSTS:	
MATERIALS (WITH 15% G&A):	17329.52
MACHINING:	1170.00
TECHNICIAN LABOR:	216.00
SUBTOTAL:	18715.52
CONTINGENCIES:	
MATERIALS:	10%
MACHINING:	50%
TECHNICIAN LABOR:	50%
TOTAL RECURRING COSTS:	21141.47475
NON-RECURRING COSTS:	
ENGINEER:	5750.00
TECHNOLOGIST:	1248.00
DRAFTING:	1638.00
TECHNICIAN:	1512
MATERIALS:	904.8775
MACHINING:	1560
SUBTOTAL:	12612.88
CONTINGENCIES:	
ENGINEER:	100%
TECHNOLOGIST:	100%
DRAFTING:	100%
TECHNICIAN:	100%
MATERIALS:	100%
MACHINING:	100%
TOTAL NON-RECURRING COSTS:	25225.76

PROBE ASSEMBLY-CENTRALIZED DWG B-SK-0900

ALL COSTS ARE PER UNIT BASED ON MAKING 1 UNIT

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG		DRAFTING		ENGEERING		TECHNOLOGIST		TECHNICIAN	
						(HRS)	$	(HRS)	$	(HRS)	$	(HRS)	$	(HRS)	$
1	1	1205	NEUTRON-NEUTRON PROBE	1.25" OD; 16" SPACING/RESLTN; COMPROBE	3392.5		0.00								
2	1	93800-000	NEUTRON SOURCE	AMERICIUM-BERYLLIUM; 3 CURRIE; COMPROBE	10584.6										
3	1	4000-002	SOURCE SHIELD ASSY	COMPROBE	2714										
4	1	4000-015	SOURCE HOLDER	COMPROBE	325.68										
5	1	4000-026	NEUTRON CALIBRATOR	ACRYLIC TUBE TYPE; COMPROBE	2442.6										
6	1	1204LT	GAMMA RAY PROBE	1.25" OD; COMPROBE	3345.005										
7	1	9381-001	GAMMA CALIBRATOR	200 API FOR 1.25" OD PROBE; COMPROBE	1458.775										
8	1	---	FORWARD SUPPORT ASSY-BQ	BODY+CENTRALIZING COMPONENTS, 4" LG	20	4.00	156.00	8.00	312.00	16.00	1000.00				
	1	---	FORWARD SUPPORT ASSY-HQ	BODY+CENTRALIZING COMPONENTS, 4" LG	20	4.00	156.00	1.00	39.00	2.00	125.00				
	1	---	FORWARD SUPPORT ASSY-HQ	BODY+CENTRALIZING COMPONENTS, 4" LG	20	4.00	156.00	1.00	39.00	2.00	125.00				
	1	---	REAR SUPPORT ASSY-BQ	BODY+CTRLZG & SEALG COMPONENTS, 8" LG	50	6.00	234.00	6.00	234.00	12.00	750.00				
	1	---	REAR SUPPORT ASSY-HQ	BODY+CTRLZG & SEALG COMPONENTS, 8" LG	50	6.00	234.00	1.00	39.00	2.00	125.00				
	1	---	REAR SUPPORT ASSY-HQ	BODY+CTRLZG & SEALG COMPONENTS, 8" LG	50	6.00	234.00	1.00	39.00	2.00	125.00				
			ASSEMBLY:											8	216
				TOTALS:	24473.16	30.00	1170.00	18.00	702.00	36.00	2250.00	0.00	0.00	8.00	216.00
			TEST & EVALUATION-PROBE:	DETERMINE IF PROBES ARE INTR'Y SAFE MAKE MODIFICATIONS AS REQUIRED OBTAIN CERTIFICATION	200.00	24.00	936.00	24.00	936.00	40.00	2500.00	40	1560	32	864
			TEST & EVALUATION-SEALING AND SUPPORT:	DO SEAL AND SUPPORT TESTS IN 1 LENGTH OF DRILL PIPE. MAKE MODS AS REQUIRED.	100	24	936.00	16.00	624.00	32.00	2000.00	0	0	32	864

RECURRING COSTS:	
MATERIALS (WITH 15% G&A):	28144.13
MACHINING:	1170.00
TECHNICIAN LABOR:	216.00
SUBTOTAL:	29530.13
CONTINGENCIES:	
MATERIALS:	10%
MACHINING:	50%
TECHNICIAN LABOR:	50%
TOTAL RECURRING COSTS:	33037.5474
NON-RECURRING COSTS:	
ENGINEER:	6750.00
TECHNOLOGIST:	1560.00
DRAFTING:	2262.00
TECHNICIAN:	1728
MATERIALS:	345
MACHINING:	1872
SUBTOTAL:	14517.00
CONTINGENCIES:	
ENGINEER:	100%
TECHNOLOGIST:	100%
DRAFTING:	100%
TECHNICIAN:	100%
MATERIALS:	100%
MACHINING:	100%
TOTAL NON-RECURRING COSTS:	29034.00

GEOPHYSICAL CABLE ASSEMBLY

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1	1	4-1H-185	CABLE - ROCHESTER CORP	4 COND; ARMOURED; 3/16" DIA X 1200' LG	1270.6948										
2	1	1200-001	CABLE HEAD	1.25" OD; 4 CONDUCTOR; COMPROBE	474.95										
				TOTAL RECURRING COST:	1745.6448										
				TOTAL NON-RECURRING COSTS:	0										

WINCH ASSEMBLY

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1	1		WINCH	BUILT TO SPECS BY COMPUTALOG	33925					48	3000.00	0	0	32	864
				RECURRING COSTS:											
				MATERIALS (WITH 15% G&A):	39013.75										
				TECHNICIAN LABOR:	864.00										
				SUBTOTAL:	39877.75										
				CONTINGENCIES:											
				MATERIALS:	10%										
				TECHNICIAN LABOR:	50%										
				TOTAL RECURRING COSTS:	44211.125										
				NON-RECURRING COSTS:											
				ENGINEER:	3000.00										
				CONTINGENCIES:											
				ENGINEER:	50%										
				TOTAL NON-RECURRING COSTS:	4500										

ELECTRONICS MODULE

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG		DRAFTING		ENGINEER		TECHNOLOGIST		TECHNICIAN	
						(HRS)	$	(HRS)	$	(HRS)	$	(HRS)	$	(HRS)	$
1	1		CASE	DESIGN, HARDWARE & MACHG	1200	37.50	1462.50	37.50	1462.50	37.50	2343.75	37.5	1462.5	0	0
2	1		BATTERY & BOX	DESIGN, HARDWARE & MACHG	350	7.5	292.50	7.50	292.50	15.00	937.50	15	585	0	0
3	1		BATTERY CHARGER	DESIGN, HARDWARE, ASSEMBLY & TEST	300	0	0.00	7.50	292.50	22.50	1406.25	22.5	877.5	15	405
4	1		DC/DC CONVERTER & PWR SUPPLY	DESIGN, HARDWARE, ASSEMBLY & TEST	700	0	0.00	15.00	585.00	30.00	1875.00	30	1170	15	405
5	1		INTERFACES	TOOL SIG, WINCH COUNTER, ANALOG OUTPUT	800	0	0.00	26.25	1023.75	45.00	2812.50	45	1755	22.5	607.5
6	1		PROCESSOR	DESIGN, HARDWARE, ASSEMBLY & TEST	2500	0	0.00	0.00	0.00	15.00	937.50	52.5	2047.5	0	0
7	1		KEYBOARD/DISPLAY	PURCHASE, PROGRAM & TEST	2200	0	0.00	0.00	0.00	15.00	937.50	15	585	0	0
8			MODULE ASSY & TEST	SOURCE & PURCHASE	0	0	0.00	0.00	0.00	37.50	2343.75	37.5	1462.5	37.5	1012.5
				TOTALS:	8050	45	1755	93.8	3656.3	217.5	13593.75	255	9945	90	2430

RECURRING COSTS:	
MATERIALS (WITH 15% G&A):	9257.50
MACHINING:	1755.00
TECHNICIAN LABOR:	2430.00
SUBTOTAL:	13442.50
CONTINGENCIES:	
MATERIALS:	10%
MACHINING:	50%
TECHNICIAN LABOR:	50%
TOTAL RECURRING COSTS:	16460.75
NON-RECURRING COSTS:	
ENGINEER:	13593.75
TECHNOLOGIST:	9945.00
DRAFTING:	3656.25
SUBTOTAL:	27195.00
CONTINGENCIES:	
ENGINEER:	100%
TECHNOLOGIST:	100%
DRAFTING:	100%
TOTAL NON-RECURRING COSTS:	54390.00

SEAL TEE ASSEMBLY

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1	1		SEAL TEE-BQ	MODIFIED LONGYEAR BQ SEAL TEE	600					2	125.00	0	0	0	0
2	1		SEAL TEE-NQ	MODIFIED LONGYEAR NQ SEAL TEE	700					2	125.00	0	0	0	0
3	1		SEAL TEE-HQ	MODIFIED LONGYEAR HQ SEAL TEE	900					2	125.00	0	0	0	0
					2200.00	0.00	0.00	0.00	0.00	6.00	375.00	0.00	0.00	0.00	0.00
				RECURRING COSTS:											
				MATERIALS (WITH 15% G&A):	2530.00										
				TECHNICIAN LABOR:	0.00										
				SUBTOTAL:	2530.00										
				CONTINGENCIES:											
				MATERIALS:	10%										
				TECHNICIAN LABOR:	50%										
				TOTAL RECURRING COSTS:	2783										
				NON-RECURRING COSTS:											
				ENGINEER:	375.00										
				CONTINGENCIES:											
				ENGINEER:	50%										
				TOTAL NON-RECURRING COSTS:	562.5										

WATER MANIFOLD ASSEMBLY

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1	2		VALVE	1/2" MANUAL SHUT OFF; 1000 PSI WP.	200										
2	1		PRESSURE GUAGE	3" DIA; 1/4 NPT; 0-600 PSIG; BACK MOUNT	50										
3	2		FLOWMETER	HEADLAND INLINE; 0-40 USGPM; 1000 PSI WP	300										
4	1		RELIEF VALVE	550 PSI RELIEF	100										
5			STEEL BOX/PANEL	HAMMOND OR EQUIVALENT	100	8.00	312.00	8.00	312.00	8.00	500.00	0	0	0	0
			CIRCUIT	DESIGN				16.00	624.00	16.00	1000.00	0	0	0	0
			ASSEMBLY											24	648
				TOTALS:	750.00	8.00	312.00	24.00	936.00	24.00	1500.00	0.00	0.00	24.00	648.00
			TEST HYDRAULICS:	HOOK UP TO WATER PUMP AND TEST FLOW AND PRESSURE PARAMETERS	200.00					2	3000.00	0.00	0.00	48.00	1296.00
				RECURRING COSTS:											
				MATERIALS (WITH 15% G&A):	862.50										
				MACHINING:	312.00										
				TECHNICIAN LABOR:	1944.00										
				SUBTOTAL:	3118.50										
				CONTINGENCIES:											
				MATERIALS:	10%										
				MACHINING:	50%										
				TECHNICIAN LABOR:	50%										
				TOTAL RECURRING COSTS:	4332.75										
				NON-RECURRING COSTS:											
				ENGINEER:	4500.00										
				TECHNOLOGIST:	0.00										
				DRAFTING:	936.00										
				TECHNICIAN:	0										
				MATERIALS:	230										
				MACHINING:											
				SUBTOTAL:	5666.00										
				CONTINGENCIES:											
				ENGINEER:	50%										
				TECHNOLOGIST:	50%										
				DRAFTING:	50%										
				TECHNICIAN:	50%										
				MATERIALS:	50%										
				MACHINING:	50%										
				TOTAL NON-RECURRING COSTS:	8499.00										

ACCESSORIES

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1	1		POWER PACK (OPTIONAL)	BUILT TO SPECS BY DESIGN HYDRAULICS	3700					48	3000.00	0	0	4	108
2	1		WATER PUMP	LONGYEAR 535H CW SKID, HYD MOTOR, 15' HOSES, CONTROL VALVE & PLUMBING	9000					4	250.00	0	0	4	108
				TOTALS:	12700.00	0.00	0.00	0.00	0.00	52.00	3250.00	0.00	0.00	8.00	216.00
				RECURRING COSTS:											
				MATERIALS (WITH 15% G&A):	14605.00										
				TECHNICIAN LABOR:	216.00										
				SUBTOTAL:	14821.00										
				CONTINGENCIES:											
				MATERIALS:	10%										
				TECHNICIAN LABOR:	50%										
				TOTAL RECURRING COSTS:	16389.5										
				NON-RECURRING COSTS:											
				ENGINEER:	3250.00										
				CONTINGENCIES:											
				ENGINEER:	50%										
				TOTAL NON-RECURRING COSTS:	4875										

SYSTEM TEST AND EVALUATION

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1			TEST PROBE INSERTION METHOD												
			BUILD TEST STRUCTURE	100 FT OF BQ SIZE DRILL PIPE	973.00										
				2000' OF 3/8" STEEL CABLE	960.00										
				132 FT OF STL PIPE	241.56										
				4 COME-ALONGS	886.07										
				STRUCTURAL STEEL	200.00										
				ASSECORIES	130.88										
				LABOR		16.00	624.00	24.00	936.00	32.00	2000.00	80	3120	0	0
			SET UP LOGGING EQUIPMENT	SEAL TEE ASSY, WATER CONTROL MANIFOLD, WATER PUMP, GEO WINCH, HYD PWR PACK	200.00	8	312.00	0.00	0.00	4.00	250.00	40	1560	0	0
			RUN TESTS	MEASURE LINE TENSION, LINE SPEED, AND WATER PRESSURE FOR HORIZONTAL, 45 DEG AND VERTICAL HOLES		0	0.00	0.00	0.00	40.00	2500.00	80	3120	0	0
2			TEST DATA ACQUISITION												
			HOOK UP EQUIPMENT	ELECTRONICS MODULE		0	0.00	0.00	0.00	16.00	1000.00	16	624	0	0
			RUN TESTS			0	0.00	0.00	0.00	40.00	2500.00	40	1560	0	0
				TOTALS:	3591.51	24.00	936.00	24.00	936.00	132.00	8250.00	256.00	9984.00	0.00	0.00

TOTAL COSTS:	
ENGINEER:	8250.00
TECHNOLOGIST:	9984.00
DRAFTING:	936.00
TECHNICIAN:	0.00
MATERIALS (WITH 15% G&A):	4130.24
MACHINING:	936.00
SUBTOTAL:	24236.24
CONTINGENCIES:	
ENGINEER:	100.00%
TECHNOLOGIST:	100.00%
DRAFTING:	100.00%
TECHNICIAN:	100.00%
MATERIALS:	100.00%
MACHINING:	100.00%
TOTAL NON-RECURRING COSTS:	48472.47

MANUALS

ITEM	QTY	REF NO.	NAME	DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $
1	1			WRITE MANUAL	50.00	0	0.00	16.00	624.00	160.00	10000.00	24	936	0	0
				TOTAL RECURRING COSTS:	50.00										
				TOTAL NON-RECURRING COSTS:	11560.00										

SOFTWARE DEVELOPMENT

DESCRIPTION	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	PROGRAMMER (HRS)	PROGRAMMER $
PLANNING		0	0.00	0.00	0.00	40.00	2500.00	40	1560	0	0
PROGRAMMING										640	25600
TOTAL SOFTWARE DEVELOPMENT:	29660										

TOTAL SYSTEM

TOTAL DESIGN & DEVELOPMENT COST:	169811.79
TOTAL FABRICATION COST:	187118.73
TOTAL FIRST UNIT COST:	356930.52 $CDN
ESTIMATED SPARES COST (20% OF FAB COST):	37423.75

	MATL	MACHG (HRS)	MACHG $	DRAFTING (HRS)	DRAFTING $	ENGINEER (HRS)	ENGINEER $	TECHNOLOGIST (HRS)	TECHNOLOGIST $	TECHNICIAN (HRS)	TECHNICIAN $	PROGRAMMER (HRS)	PROGRAMMER $
TOTAL FABRICATION COSTS BY CATEGORY:	113807.40		4407		0		0		0	218	5886	0	0
TOTAL DESIGN & DEV'T COSTS BY CATEGORY:	5610.11		4368	258	10052	837.5	57718.75	607	25233	120	3240	640	25600

DESIGN ENHANCEMENTS PHASE

TOTAL DESIGN & DEVELOPMENT COSTS:	84905.90
TOTAL FABRICATION COST BASED ON 6 UNITS:	110146.41
CONTINGENCY ON FABRICATION (50%):	165219.61
UNIT FABRICATION COST BASED ON 6 UNITS:	27536.60
UNIT FAB COST INCDG 1ST UNIT & DES & DEV:	101176.00
UNIT PRICE WITH 30% MARGIN:	144537.15

8 SUMMARY AND CONCLUSIONS

1. The conceptual design shows that an In Mine Geophysical Borehole Logging System with above horizontal, horizontal or below horizontal logging capability is a practical proposition. The system includes components which would either be explosion proof, intrinsically safe or certified for "special protection" or a combination of these regulatory requirements for safe operation in a coal mine.

2. Existing manufactured probes have been identified which fulfil most of the requirements of the In Mine Geophysical Borehole Logging System. However, one requirement which has not been met is the vertical resolution (± 3 cms or ± 1.2 inches). Estimated vertical resolutions for the gamma ray, gamma-gamma (density) and neutron-neutron probes are 6.35 cms, 10.16 cms and 40.6 cms respectively. It is doubtful that the ± 3 cm specification can be obtained due to the limitations of slimhole probe geometry and design.

3. Probes may require modification so that they are explosion proof, intrinsically safe or certified under the "special protection" category. This will not be known until probe drawings and schematics are available.

4. A suitable geophysical logging cable and cable head are available from the manufacturer.

5. The winch will be a modified version of an existing manufacturer's design to address the In Mine standards and requirements regarding materials and drive configuration. The winch will be hydraulic and its power pack will operate using the coal mine electrical power supply.

6. Above horizontal or horizontal geophysical logging capability will be satisfied by a hydraulic pressurization method. This will be a variation of existing methods. The water pump required will be powered by the same hydraulic unit as the winch.

7. The electronics module, including keyboard, display and power pack, is designed specifically for the In Mine Logging System to meet the requirements of safe underground coal mine operations. A battery pack will be used to power both the probes and the electronic module.

8. An outline of the software requirements is included but a requirements profile cannot be completed until the processor and other electronics hardware are specified.

9. The total estimated break even cost of producing one In Mine Geophysical Borehole Logging unit is approximately $357,000 Canadian excluding applicable taxes. Estimated spares cost for this unit is approximately $38,000 Canadian. Costings for subsequent upgrades, training, operating, maintenance and repair are not included.

10. If six units are manufactured, the cost per unit is approximately $145,000 Canadian which includes a 30% profit on each unit. This price excludes applicable taxes and spares. This includes some monies for subsequent upgrades of the first unit, but does not contain costs for training, operating, maintenance and repair.

11. The market study has shown the market to be small for this very specialized piece of equipment, though it was unable to accurately quantify the potential for such a system.

12. The market study has identified a number of existing systems and methods for logging horizontally and above the horizontal. A new system would need to be better than or competitive with existing systems.

13. The current market for the proposed system is estimated to be 3 to 5 units. There is a good opportunity that parts of the system may find applications in other, related markets.

14. An industrial partner will require complete funding if only one unit is constructed and would need evidence of a good market and profits if it is to become a production item.

15. Possible industrial partners in Canada include The Cord Group, Dartmouth; Computalog Wireline Products Inc., Calgary, Alberta; Roke Oil Enterprises Ltd., Calgary, Alberta and Scintrex Ltd., Toronto, Ontario. A consortium may be required to tackle all aspects of this project.

16. Possible industrial partners in the USA include Comprobe Inc., Fort Worth, Texas and Neltronic International Corp., Houston, Texas.

9 RECOMMENDATIONS

1. To enhance and improve the capability of Canadian Industry it is recommended that one unit be constructed by a Canadian industrial partner for use by the Cape Breton Development Corporation in the underwater coal mines of the Sydney coalfield.

2. That this system be then used as a demonstration unit for marketing and that a decision be made by the industrial partner as to whether the market is sufficient to warrant a limited production run. If the logging system becomes a saleable product, then the industrial partner would be given full rights to the design.

3. That complete funding be given to the industrial partner if only a single unit is manufactured with additional funding for a subsequent upgrade about 6 to 12 months after completion of the manufacture of the unit.

4. That Canadian industrial partners be given first opportunity to take up this project.

5. That the Nova Scotia Research Foundation Corporation act as client representative on the design/fabrication project phase to follow the conceptual design phase (this report) and that NSRFC is also responsible for the operation, maintenance and repair of the system.

6. That if a unit(s) is not constructed then WBK, Bochum, Germany is approached to purchase their existing In Mine Logging System providing that their probes can be redesigned so that their outside diameters are reduced from 60 mm to 33 mm or less.

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APPENDIX 3.1

VISITS TO CANADIAN MANUFACTURERS

VISITS TO CANADIAN MANUFACTURERS

1. MONDAY, AUGUST 13, 1990

A. Scintrex
222 Snidercroft Rd.
Concord, Ontario
L4K 1B5

Telephone: (416) 669-2280
FAX: (416) 669-5132

John G. Baird, B.Sc., P.Eng.
Senior Vice President and General Manager
Earth Science Division

Scintrex manufacture gamma ray spectrometers for borehole logging, but sales are obviously sparse. None in stock, no winches in stock. No sales figures given (advertised in brochure). They had developed a geophysical borehole logging system with γ ray, resistivity and density to point of entry in market, but previous recession and competition caused cancellation of product. Neutron prompt γ ray borehole logging system developed by Dr. Nagarwalla was a technical success (assays of minerals in gold, base metals, ash in coal) but not accepted by mining industry due to favouring of assay from cores. We believe this is not the whole story, eg: high cost of system, large diameter probe and stopping to take readings in the borehole (time factor).

Scintrex not interested in in-mine logger until after prototype development state and even then it is on the periphery of or out of their area of expertise, ie: needs proven market to sell systems. Not comfortable with this project unless very profitable.

Discussed uphole logging possibilities - push rods, hydraulic method with water swivel. Marketing philosophy - early marketing dubious due to lack of definite commitment by potential customers and lack of hard facts about specifications (eg: cost, capability, availability, delivery, etc.).

Tour of plant - saw new Scintrex gravimeter. Cost = \$35 - \$40K. Comparable to Lacoste and Romberg equivalent.

Should talk to users for marketing (logging companies, mines & drillers). Not a lot of physical properties logging in base metals. Small percentage of uphole logs. Scintrex also manufacture downhole pulsed EM logging system.

Scintrex into explosive detection (sniffers) NRC development - research project still in progress. Environmental Company (Unisearch Assoc) 1/4 owned by Scintrex - gas analysis, air quality.

B. Quantech Consulting Inc.
Suite 304, 2121 Argentia Rd.
Mississauga, Ontario
L5N 2X4

Telephone: (416) 567-0155
FAX: (416) 567-8117

David C. Anderson (President/Director)
and
S. T. (Woody) Coulson (Operations Manager)

They own two Geonics downhole pulsed EM systems for base metal exploration. Lot of work and have diversified out of country (office in Reno); work in USA and South America.

They see need for horizontal and uphole logging in mines (base metal). Have done testing of borehole device to attach at bottom (top) of borehole with eye for cable/string. Cheap component to put in hole and leave there.

Want us to see if it can be used and if development can be continued. Really need to use themselves. Would like to retrieve $5,000 invested to date. With this device could log inclined holes starting at downward angle and flattening out so gravity does not exceed frictional forces.

Can leave device in hole and return later for cheaper logging operations. More expensive methods include Crone flexible push rod system (on winch), Hudson Bay hydraulic method (need drill rig) and the Longyear pushing system (hydraulic hammer).

C. Terraplus Inc.
52 West Beaver Rd., Unit 14
Richmond Hill, Ontario
L4B 1L9

Telephone: (416) 764-5505
FAX: (416) 764-9329

Claude Meunier
President

President of ABEM is very interested in NSRFC project. Possible problem with Canadian money and Swedish Company. ABEM Welmac logger only just on market (no brochures) and will be competing against proven systems already in existence. γ ray and $\gamma\gamma$ probes in existence, but no neutron to date.

They have logged from horizontal to up to 75° from horizontal using push rods to a couple of hundred feet in hard rock mines. Little information on construction, specs, resolution, etc. of logging system. No equipment to see.

Network of companies: ABEM, Terraplus, GEM, Phoenix all interrelated. Thought we had funding for next phase.

ABEM principals interested in meeting. SEG meeting in September 1990 in San Francisco with new logger on display. Integrate with visit to US manufacturers. Brochures may now be available (January, 1991).

2. TUESDAY, AUGUST 14, 1990

D. Longyear Canada Inc.
111 Main St. West
P. O. Box 330
North Bay, Ontario
P1B 8H6

Telephone: (705) 474-2800
FAX: (705) 474-2373

Murray Etherington, P.Eng.
Manager of Engineering

Overview of drilling equipment - drills, drill pipe, overshot, core barrels, etc. Looked at details of overshot and water swivel.

Went on tour of plant with Richard Anderson (designer) - in stock room showed actual overshots and water swivel. Saw 38 EHS drills under construction.

Longyear is diamond drilling equipment (US company).

Brainard - Kilman, Atlanta, GA - geotechnical (?geophysical) company owned by Longyear. May make equipment for logging.

Slope Indicator in Washington, DC - deviation equipment.

Morissette, Haileybury, Ontario - drilling contractor owned by Longyear. Carry out a lot of underground drilling.

Longyear not in geophysical logging at all. Could supply parts, but not industrial partner/manufacturer for in-mine logger (no geophysics expertise). Could work with them for pumped probe mechanism (water swivel). Could make pipe adaptor.

Longyear winch - ready made, hydraulic operation for Longyear drill. Made of steel (heavy). Possible for logging winch.

For water swivel, size of cable packing for different size cables.

New drilling ideas - flexibility in working arrangements, but no mention of geophysical logging. Out of their area of expertise.

Tour of drill rod/pipe shop. Good machine shop, CAD/CAM 350, employees in North Bay; 2,500 worldwide; 200 - 250 at Morissette.

Gary Ball - Drilling contracts (ex Sydney River). Make equipment simple to operate, useable by mine geologist. No problem pushing rods (?drill rods) up 1000 foot hole. Needs more discussion. 2 - 3 underground drill holes to every surface hole in Canadian mining. 200 underground drills in Sudbury, 2000 across Canada. Approach mining companies to find out demand. Polymer mud used in drilling.

1/8" cable	AQ	
3/16" cable	BQ	Packer charges
	NQ	
1/4" cable	HQ	

Mining Companies

Noranda
Inco In Sudbury
Falconbridge
Hudson Bay

Morissette Dave Fowler (President)

Mining Operations

1 3/32" (RW)
standard drill rod

AQ=2"

Drill with polymer mud in coal mines (soft rock). Hard rock mines use very little polymer mud or linseed soap (raise viscosity). Brass overshot used in areas where steel rods become magnetized. Downhole motors (Navidrill - Timmins) used in hydralic areas where holes deviate continuously and cannot be controlled.

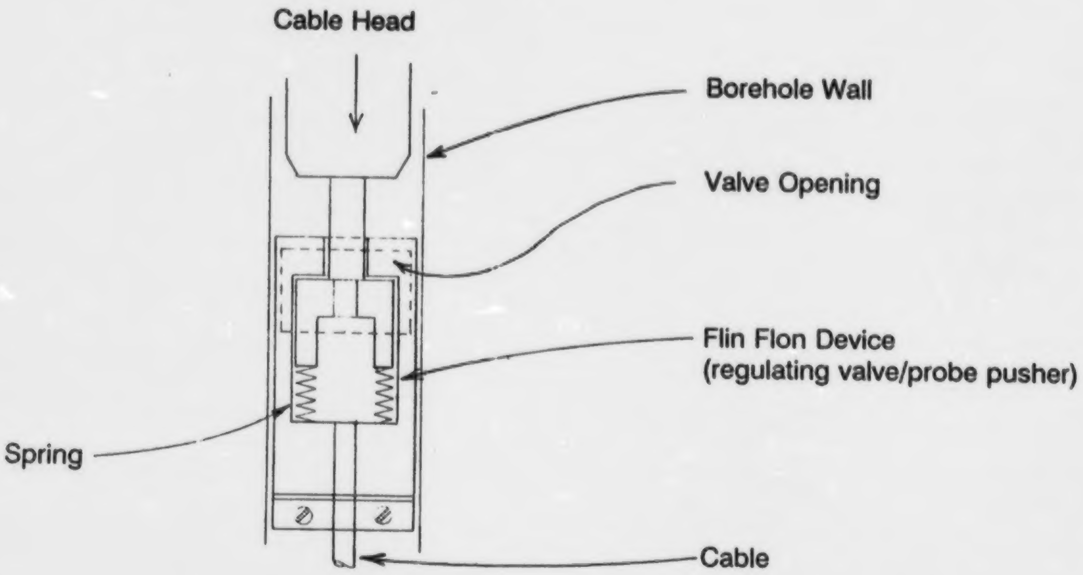
3. WEDNESDAY, AUGUST 15, 1990

E. Hudson Bay Mining Limited
Flin Flon, Manitoba

Telephone: (204) 687-2228

Ted Baumgartner, Manager
Dan MacKechnie, Technician
Alan Vowles, Geophysics Technician (absent)

Probe pushing device. Original idea concieved by Alan Vowles. Engineered out by Winnipeg Company who now have drawings.

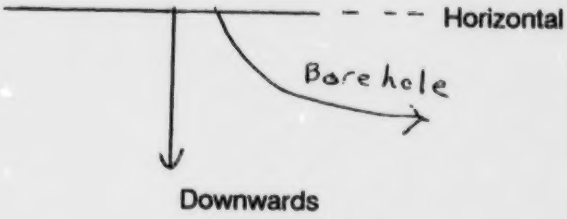

Cable Head
Borehole Wall
Valve Opening
Flin Flon Device
(regulating valve/probe pusher)
Spring
Cable

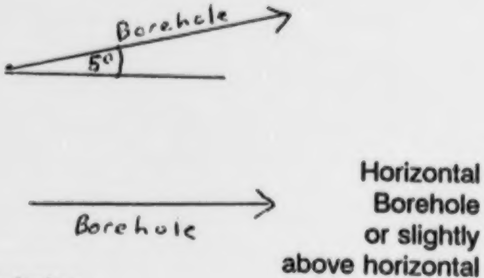
Plastic rods (PVC) with threaded ends to push up drill hole casing.

Water packing device (see photostat)

Ted Baumgartner - market opinion. Little or no market in the base metal industry. Most holes drilled downwards.

Two cases where this device needed:


Horizontal
Borehole
Downwards


Borehole
5°
Borehole
Horizontal Borehole or slightly above horizontal

1500 - 2000 feet long holes

Needed to do it for pulsed EM surveys.

4. **THURSDAY, AUGUST 16, 1990**

F. Computalog Manufacturing Ltd.
7210 Blackfoot Trail SE
Calgary, Alberta
T2H 1M5

Telephone: (403) 258-8255

Wayne Gillespie, Vice President
Wireline Services Division, Computalog Ltd.

Darcy Meyer, Marketing/Production Engineer (Mechanical)
Computalog Manufacturing Ltd.

Steve Buconjic, Manager
Computalog Manufacturing Ltd.

Computalog Manufacturing Ltd. have constructed an in-mine explosion proof borehole logging system for the Tar Sands Project funded by AOSTRA (Calgary and Fort McMurray) program run by the Alberta Provincial Government. It was not clear who owned the rights to the design of this system. Specifications and detailed description were not available, but two photographs of the in-mine part of the system were provided (see attached). The AOSTRA contact is Mr. Gord Trefenanko (Drilling Supervisor) at (403)-279-3380. AOSTRA is the Alberta Oil Sands Technology Research Authority.

The system consists of the winch, cable, slip ring and winch operating system in a steel frame designed to protect the system in the event of roof collapse. We were not aware that explosion proofing required this type of protection. Are there further unknown design requirements? This in-mine/explosion proof part of the system is connected by a 500 metre long signal/?power cable to the ? modules and recording equipment at the surface. Recording equipment and modules are not explosion proof. Communication between the in-mine and surface operators is by radio or radio/telephone. The in-mine operator would connect the appropriate logging probes to the cable head and insert in the hole and retrieve after logging. Presumably testing of the probes took place at the surface together with setting of recording and probe module parameters. This arrangement is not satisfactory for in-mine coal logging due to the distance between the areas to be logged and the surface (1.0 - 1.5 miles) together with the conveyor belt system, railway, and airlocks and other equipment in the access tunnels in a coal mine. We need more details about this system (eg: probes available, specifications, dimensions, power required, electronic/electrical parameters).

Computalog have logged horizontally and upward with this system, but not vertically upward. Their maximum angle above the horizontal is about 30°. They have used push rods and a water pumping system, but no details were given. They also discussed an uphole logging procedure where the probe is attached to the end of the drill rods in the open hole and the hole is logged while pulling out the drill rods. This is described in the Computalog Toolpusher Logging System. However, this does not appear to have been used with the in-mine logging system as the minimum hole diameter is given as 5 1/2 ins. and the tool diameter as 2 3/4 ins. which are too large for NQ or BQ diamond drill holes. A major redesign would be required to downsize this system for diamond drill holes used for coal exploration in Nova Scotia.

Similarly, probe sizes from the Computalog Product catalog indicate that their open hole probes are too large (3 1/4" - 4" diameter or 83 mm - 102 mm). For cased hole measurements, the Computalog gamma ray/neutron/CCL probe with a 1 inch (25 mm) OD may be suitable if its length is not too great and its resolution is satisfactory. Length and resolutions of the probes are not given in the tool specifications. A cased hole density (gamma-gamma) probe does not appear to be manufactured by Computalog other than the "Gravel Pack Density" probe with an OD of 1 11/16" (43 mm). This OD is too big for BQ Holes. Also, resolution is not stated. For the probes we must conclude that Computalog would have to downsize probe sizes and improve probe resolution for coal mine geophysical logging. An alternative would be to purchase geophysical probes from other manufacturers, possibly with the modules, to incorporate in the logging system.

Computalog are looking for work and have spare capacity. The probes and modules are designed and constructed in Fort Worth, Texas.

G. Roke Oil Enterprises Limited
516 Moraine Road, N.E.
Calgary, Alberta
T2A 2P2

Telephone: (403) 273-5553
(403) 262-9894 (24 hour)
FAX: (403) 273-9818

Keith M. Banks, P.Eng., President

Keith Banks is the driving force behind this small company which has fallen on lean times. In its heyday (late seventies/early eighties) it had fifteen logging trucks with an innovative research arm. At present it has two logging trucks with seven employees and no research arm. This company is the Canadian distributor for Widco logging equipment for which it also carries out repairs and maintenance.

Roke specializes in high resolution slim hole logging and has expended considerable efforts in designing and constructing equipment for its own use. This includes modification of trucks, winches, probes and modules with construction of probes and modules to its own design together with its own high speed computer and software to output data onto digital tape cassettes. One of the probes highlighted by Mr. Banks was their Quad Neutron Probe which can measure matrix porosity, clay content, coal porosity and salt water/methane content. This probe, with gamma ray scintillometer, is 14.8 feet (451.17 cms) in length with an OD of 1 11/16" (43 mm). The gamma ray scintillometer would have 70 keV cut off. The probe would include the quad neutron, gamma ray, telemetry, temperature, cable head and bullnose - plus bottom sections. It appears to be too long, have too large a diameter and too expensive ($120,000.00) for our purposes. The quad neutron section comprises a neutron source with two detectors on each side of the source. However, this method is not patented and Roke would require an agreement with the customer that the design not be copied by the purchaser or any other party.

Mr. Banks emphasized quality and obviously has innovative, well designed and constructed equipment. However, he has never manufactured equipment for sale to third parties. There are minimal write-ups or specifications for his probes. Some of their interpretation methods combine resistivity and density which is not possible in a cased hole.

However, he has designed and constructed successful gamma ray, neutron-neutron and gamma-gamma slim hole probes with fast counting circuits to minimize dead time effects with 1 inch 1 1/4" or 1 11/16" OD. He has carried out coal, ash, water content analyses using geophysical logs (open hole - ?cased hole). We should consider the purchase of these probes and accompanying modules from Roke to incorporate in our in-mine logging system if a suitable agreement can be arrived at.

Mr. Banks believes that new regulations by US radioactive source manufacturers for source specifications together with Canadian government regulations for R&D funding, taxes and the GST has effectively eliminated his R&D activities. He also pointed out that in Alberta the bottom had fallen out of the coal exploration business due to the low cost of oil/gas and mega coal projects whose economics were based on over estimates of coal reserves by not taking into account coal porosities. He cited several examples where Roke had shown, from their coal logs, that the actual coal reserves were less than those estimated by 15 - 25% or in one case 30 - 50%. This was bad news and Roke's honesty had not made optimists in the coal mining business happy with the conclusions. Roke has no marketing outside of Western Canada although they have come close to selling equipment or logging in Libya, Middle East, etc. These fell through due to contract problems, ie: costs.

APPENDIX A5.4

CONTACTS

CONTACTS

Geophysical Contractors and Manufacturing Companies
Major Mining and Geophysical Research Centres
Coal Research Organizations in the U.S.A., Canada, France, Germany, England
National Research Council Technology Advisors
Commercial Representatives in Canadian Embassies
Major Coal Mining Operations in Canada, U.S.A. and the U.K.

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Vibrometric OY
Finland
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Dept. of Resource Development
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Korea Mining and Promotion
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Rod Johnson
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Canadian Embassy, Warsaw, Poland
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C. Richard Mann
Canadian Embassy, Seoul, Korea
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J. Reid Henry
Canadian Embassy, Moscow, USSR
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George Philips, Sr. Trade Commissioner
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Canadian Embassy, Paris, France
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Canadian Embassy, Ankara, Turkey
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031 72363 TLX

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Canadian Embassy, Oslo, Norway
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Consulate General of Canada, Milan, Italy
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Dr. Gary VanDrunen/
Dr. R. Lepp
AECL
TEL: (613) 584-3311

Dr. Manas Das
CANMET
Devon, Alberta
TEL: (403) 987-8229

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Longmont, Colorado
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Alan Vowells
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TEL: (204) 687-2746

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Veratek Seismic
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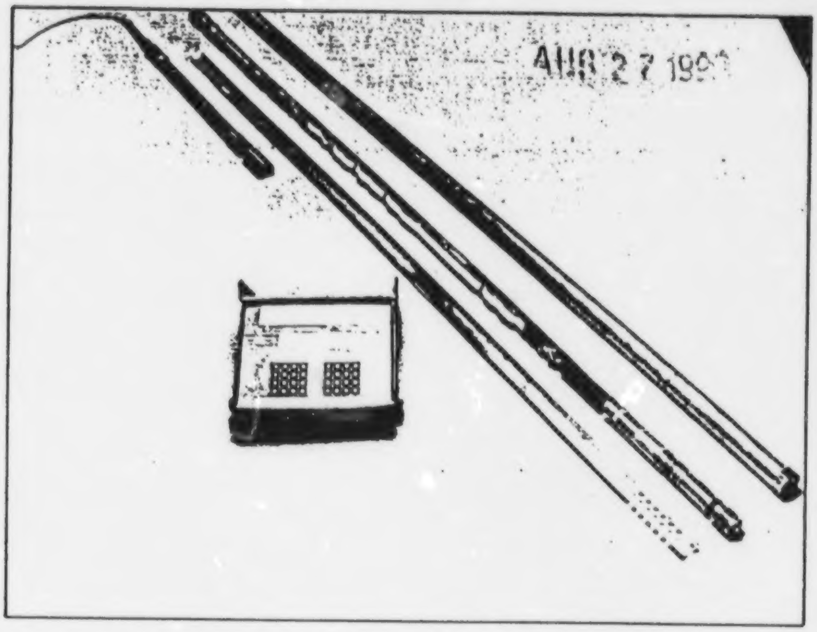
APPENDIX A5.1

BRITISH COAL CORPORATION
GUIDED LONG-HOLE DRILLING

British COAL

Headquarters Technical Department



AUG 2 7 199

Figure 1 Mk II probe and control unit

Guided longhole drilling

INTRODUCTION

The mine planning process is helped considerably if the position and scale of anomalies such as faults, washouts, etc. are accurately known. Such information allows coalfaces to be laid out so that panels of coal can be planned with greater confidence that face-stopping geological problems will not be encountered. The technique of guided longhole drilling is being developed at Headquarters Technical Department (HQTD) as a complement to the existing geophysical exploration methods of surface and in-seam seismic surveying and surface borehole logging. However, there are other potential applications, such as the remote placing of seismic sources and geophones, strata identification, underground coal gasification, the location of old workings as an aid in rescue operations, drilling cross-measures in advance of roadways, target drilling for drainage purposes and the installation of services.

If a drill can be guided to enter and remain within a coal seam and its trajectory and position relative to the seam boundaries can be determined, it becomes possible to detect the existence of a fault and measure its throw. There are two main aspects to this problem; the mechanical one of establishing the ability to drill and steer a drill bit in near-horizontal holes up to 1000 m in coal and the development of instrumentation for measuring the drill's geometric attitude and position in the seam.

DRILLING TECHNIQUES

To facilitate the steering of boreholes over distances of up to 1000 m, two techniques are available

Rotary drilling techniques can only be used in holes where relatively small steering changes are required since they rely on the effects of gravity. Also, the technique requires that the drill string configuration be changed as the steering requirement varies and this is a time consuming process involving the complete withdrawal of the drill string.

The second steering technique available eliminates the need to withdraw the drill string to change the drilling direction and involves the use of a down-hole motor (DH motor) driven by the drilling fluid. The drill string in this case does not rotate and consequently can be used for a variety of steering devices. The most commonly used of these is the bent housing which is used to offset the bit slightly from the axis of the drill string. This is possible because a universal joint coupling is used internally to connect the rotor of the DH motor to the drive shaft to which the bit is attached.

Obviously, the important feature of this technique is that steering direction can be changed easily by merely rotating the drill string. This equipment is used widely within the oil industry but has required modification to make it suitable for use underground with our surveying equipment. Steering with a DH motor is the preferred method. The technique is available for general use by the coal industry.

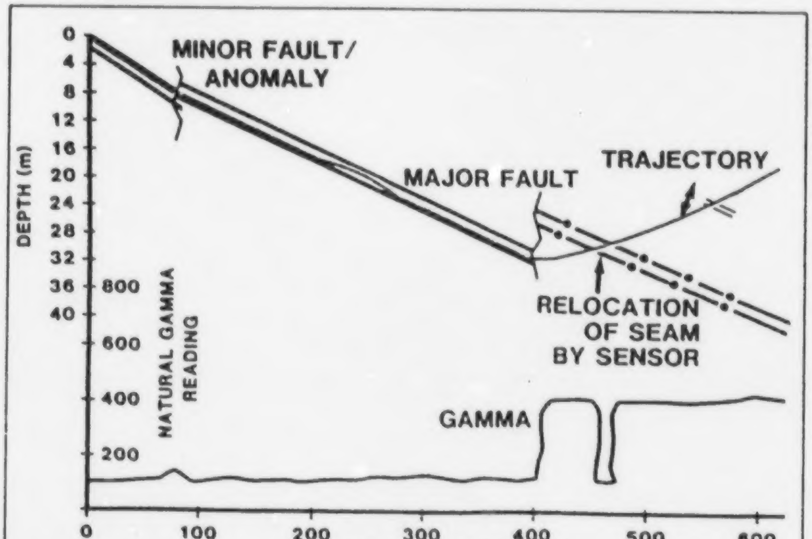


Figure 2 Example of trajectory and natural gamma readings in experimental borehole

INSTRUMENTATION

The form of the probe and ancillary equipment (Figure 1) was developed at MRDE (now HQTD) and subsequently developed to meet intrinsic safety requirements in collaboration with Salford Electrical Instruments Ltd. It is pumped down inside the drill string to the DH motor, where the measurements are made. The probe is attached to an armoured cable through which data is transmitted to a control/display unit sited near the operator (Figure 3). The cable is also used to withdraw the probe when measurements have been completed. The basic arrangement is shown in Figure 4.

The position of the probe with respect to the seam boundaries is established by measuring the natural gamma radiation field (Figure 2). The sedimentary strata above and below the coal seams generally contain a much higher proportion of radionucleides than does the coal itself. Such strata acts as a source of gamma radiation which is attenuated by absorption in the coal, hence the gamma radiation measured at the probe is a function of the thickness of coal between it and the seam boundary. The effective range of the instrument approaches 40 cm in good conditions with an accuracy of ± 1 cm. Since strata characteristics vary, it is necessary to calibrate the system at each particular site, and the presence of anomalies such as gamma active dirt bands in the coal can cause difficulties in interpretation, some experience is therefore required.

For measurement of probe orientation in the horizontal plane a magnetometer sensing the earth's magnetic field is under development. The sections of drill string behind the DH motor are made of non-magnetic material to permit the use of this technique.

The probe also contains an A-to-D converter and a modem for the transmission and reception of data and control signals, under the control of a microprocessor, which communicates with a similar microprocessor in the operator's control unit, where the keyboard also allows the time constant and threshold level of the gamma detector to be changed.

The hole depth is measured using a simple mechanical odometer on the probe cable as it feeds to and from the winch.

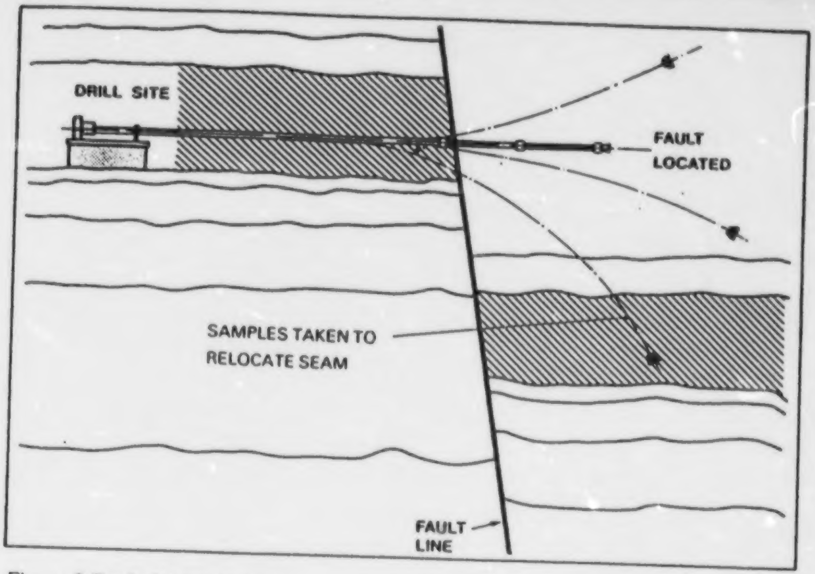

DRILL SITE
FAULT LOCATED
SAMPLES TAKEN TO RELOCATE SEAM
FAULT LINE

Figure 3 Fault determination

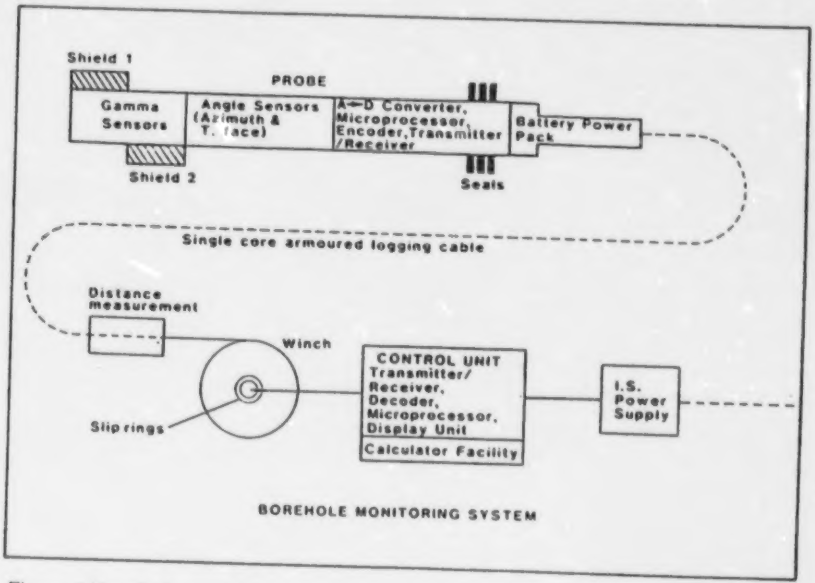

Shield 1
PROBE
Gamma Sensors
Angle Sensors (Azimuth & T. face)
A←D Converter, Microprocessor, Encoder, Transmitter /Receiver
Battery Power Pack
Shield 2
Seals
Single core armoured logging cable
Distance measurement
Winch
Slip rings
CONTROL UNIT
Transmitter/ Receiver, Decoder, Microprocessor, Display Unit
Calculator Facility
I.S. Power Supply
BOREHOLE MONITORING SYSTEM

Figure 4 Borehole monitoring system

335,6(366)

BRITISH COAL CORPORATION

TECHNICAL DEPARTMENT

GEOTECHNICAL SERVICES

GUIDED LONGHOLE DRILLING PROBE

1. GENERAL SEI MK II PROBE INFORMATION

(a) Certified to BS1259:1958 Group 1

(b) Bare probe length 2.25m to 2.50m depending upon number and type of transducers fitted.

(c) Probe assembly length (complete with battery pack and cable head) 3.45m to 3.70m

(d) Probe body diameter 50.8mm

(e) Bare probe weight 20.0kg

(f) Battery pack weight 5.7kg

(g) Control Unit weight 7.2kg

(h) Probe parameters

(i) Natural Gamma Sensor. Effective range depending upon the natural gamma activity level of the bounding strata but normally 300-350mm in good conditions.

(ii) Toolface Transducer. 360 degree range with a resolution of 0.1 degrees and approx ± 2.0 degree accuracy.

(iii) Attitude Transducer. Normal range ± 30 degrees from horizontal with a resolution of 0.01 degrees and ± 0.1 degree accuracy. (Toolface - 0) Also for range within 30-60 degrees, resolution still 0.01 degrees but accuracy better than ± 0.5 degrees. For range within 60-80 degrees, the accuracy decreases and the transducer does not work at all at 90 degrees as it is of the gravity type.

(iv) Magnetometer. BCC would not be able to recommend a probe with this facility, at this current time. Although the design and component specification is good, the magnetometer requires further calibration/setting-up before the actual performance can be assessed. (The specification which should be achievable over the full 360 degree heading range is a resolution ±0.1 degrees with an accuracy of approx ±1.0 degree).

(i) System Facilities

A number of system operating parameters, calibration routines, etc may be changed by the operator. ie. Natural Gamma thresholds and Time Constants, Transducer on/off selection, Programming outputs of transducers, Magnetometer initialisation and Analog Transducer calibration.

The system also has a calculater function.

(j) Standard NQ/NT size (2.75 inches OD 2.375 inches ID) wire line drill rods are used for this technique. The probe is pumped down the NQ/NT rods of the drill string. Probe retraction is via a wireline and winch assembly.

2. COSTS/DELIVERY

Current System Budget Cost estimate £41,000 includes 1 x Magnetometer probe, 1 x Battery Pack and 1 x Control Unit. Delivery could be up to 30 weeks if ordered from SEI Ltd, Heywood, Lancashire, England.

3. GEOTECHNICS

(a) Generally would find it difficult to supply and support a probe system outside BCC although this ultimately depends on work load and schedule of both BCC and prospective customer.

(b) Would be prepared to consider advising and training on the practical application of this probe system. This would need to be carried out within BCC's current programme of work.

(c) Although systems are improving with respect to operational reliability, BCC would not recommend operational reliance on a single probe/component system.

APPENDIX A5.2

GERMAN WBK INLOG™
BOREHOLE LOGGING SYSTEM

WBK INFORMATION

Germany

INLOG

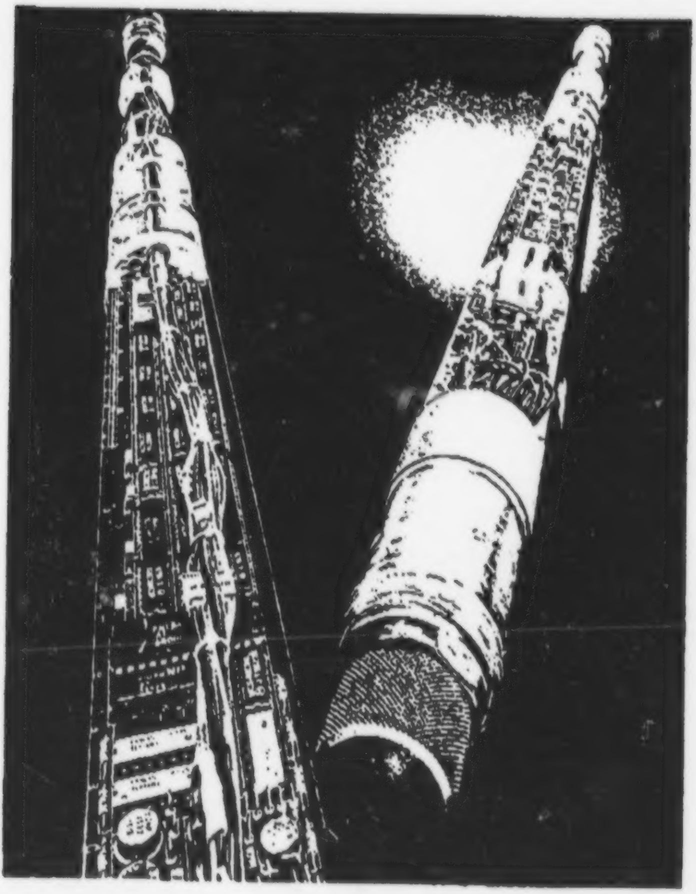
Bohrlochmessung unter Tage

The In-Mine Logging System

Ein wesentlicher Teil der Exploration auf Kohle geschieht unter Tage. Bei diesen Bohrungen mußte bisher auf Bohrlochmessungen verzichtet werden, weil kein schlagwettergeschütztes Meßgerät vorhanden war. Standardsonden, die für den Einsatz in Übertagebohrungen entwickelt wurden, können nicht eingesetzt werden, da sie nicht schlagwettergeschützt, zu groß und zu schwer sind. Die „Slim line"-Sonden aus der Mineralprospektion sind zwar klein und leicht, aber nicht schlagwettergeschützt.

Deshalb hat die WBK mit finanzieller Unterstützung des Landes Nordrhein-Westfalen das Bohrlochmeßsystem INLOG speziell für die Vermessung untertägiger Bohrlöcher entwickelt.

Das INLOG-System ist modular aufgebaut und erfüllt die EG-Bestimmungen zum Schlagwetterschutz. Es besteht aus einer Surface-Unit (Registrierstation) zur Registrierung der Meßwerte und zur Steuerung der Sonden, einer Winde mit 800 m Meßkabel, einer Umlenkrolle mit dem digitalen Teufenmeßsystem und den Sonden.



An essential part of exploration work is done in the mine itself and special tools are needed for in-mine logging operations for coal. Standard well log tools developed for boreholes drilled from the surface can not be used because in general they are not firedamp proof, are too big and too heavy. The slim line tools for mineral exploration are manageable in a mine but usually do not satisfy the firedamp regulations.

Thus an in-mine logging system (INLOG) whose components fulfill the EC firedamp regulations has been developed by the WBK-Institute for Geophysics by financial support from the government of Northrhine-Westphalia.

INLOG is a modular system which fulfills the EC firedamp regulations. It consists of a surface unit which controls the sondes and permanently stores the measured data, a winch with 800 m single conductor cable, a deviation wheel with a digital depth measuring system and the probes.

Not all in-mine drillings are vertical. A large portion of boreholes are directed horizontally or drilled upwards into the overhang thus the INLOG-system was designed to take measurements in boreholes drilled in all directions.

Blick ins Innere der schlagwettergeschützten INLOG-Sonden

Interior of the firedamp proofed INLOG probes

WBK INFORMATION

Derzeit sind Sonden zur Messung der natürlichen Gamma-Strahlung und zur Bestimmung der Gesteinsdichte verfügbar. Alle Sonden können als Sondenzug gleichzeitig gefahren werden. Die Stromversorgung der Sonden ist als erste Einheit in den Sondenzug integriert. Mit entsprechenden Kabeltreibern kann INLOG über alle gängigen Kabel betrieben werden. Für den normalen Betrieb genügt ein einadriges Kabel.

Unter Tage werden nicht nur vertikale Bohrungen durchgeführt. Viele Bohrlöcher sind horizontal oder werden ins Hangende gebohrt. Das INLOG-Meßsystem ist so ausgelegt, daß Bohrungen in jeder Richtung vermessen werden können. Messungen sind sowohl im Gestänge als auch im unverrohrten Bohrloch möglich.

Das Sondenprogramm des INLOG-Systems wird ständig ausgebaut, bis das vollständige Meßprogramm für die Kohleexploration (Schallaufzeit-, Dipmeter-, Widerstand-, Dichte- und Gamma-Sonden) vorhanden ist.

Alle Sonden enthalten eine Interface-Karte, die die Verbindung zwischen den Sensoren (Szintillationszähler etc.) und einem Mikroprozessor (Sondenprozessor) herstellt. Die Sondenprozessorkarte ist für alle Sonden gleich aufgebaut. Für die verschiedenen Aufnehmer wird lediglich ein an den jeweiligen Sondentyp und die Meßgröße angepaßtes Programm geladen. Vom Mikroprozessor wird das Signal digital übertragen.

Der modulare Aufbau der Sonden ermöglicht eine einfache Integration von Bohrlochmeßgeräten anderer Hersteller. In den Fremdsonden wird der Datenübertragungsteil durch das Standard-CPU-Board ersetzt, und für den Mikroprozessor wird ein neues, auf diesen Sondentyp abgestimmtes Programm erstellt. Der Mikroprozessor sorgt dafür, daß die Meßwerte so aufbereitet werden, daß sie zur Surface-Unit übertragen werden können.

At present, both a gamma ray and a density probe with two spacings are available. All probes can be connected into a probe string with the power supply integrated into the string. Specially adapted cable-drivers allow INLOG to operate with all common types of cables. For normal use a single conductor cable is required.

More types of tools will be developed and available for the INLOG system in the coming years, producing a complete well logging program for coal exploration (sonic, dipmeter, resistivity, density and gamma ray measurements).

All probes contain a sensor-specific interface board wich connects the sensor to the probe's microprocessor. The microprocessor board is identical in all probes. A specially adapted program can be loaded into the microprocessor for different sensors. Thus only the software has to be replaced for a new probe and the hardware is, except for the interface-board, the same for all probes. Data are transfered from the microprocessor board as a digital signal through single conductor shielded cable to the surface unit.

The modular structure of the INLOG system allows a simple integration of logging tools from other manufacturers. In these probes, the data transmission board is replaced by the INLOG microprocessor and transfer board, and a new program designed specifically for this tool is installed into the microprocessor to decode the data

Registriereinheit

Surface unit

WBK INFORMATION

Die Registrierstation enthält ebenfalls ein Mikroprozessorsystem, das die von den Sonden übertragenen Meßwerte aufnimmt und in einem Halbleiterspeicher von 1 MByte Größe ablegt. Abhängig vom Sondentyp und der Anzahl der Meßparameter können mehrere tausend Meter Bohrloch vermessen werden. Der großzügig bemessene Speicherplatz erlaubt es, mehrere Messungen nacheinander durchzuführen und abzuspeichern, ohne die Daten auszulesen.

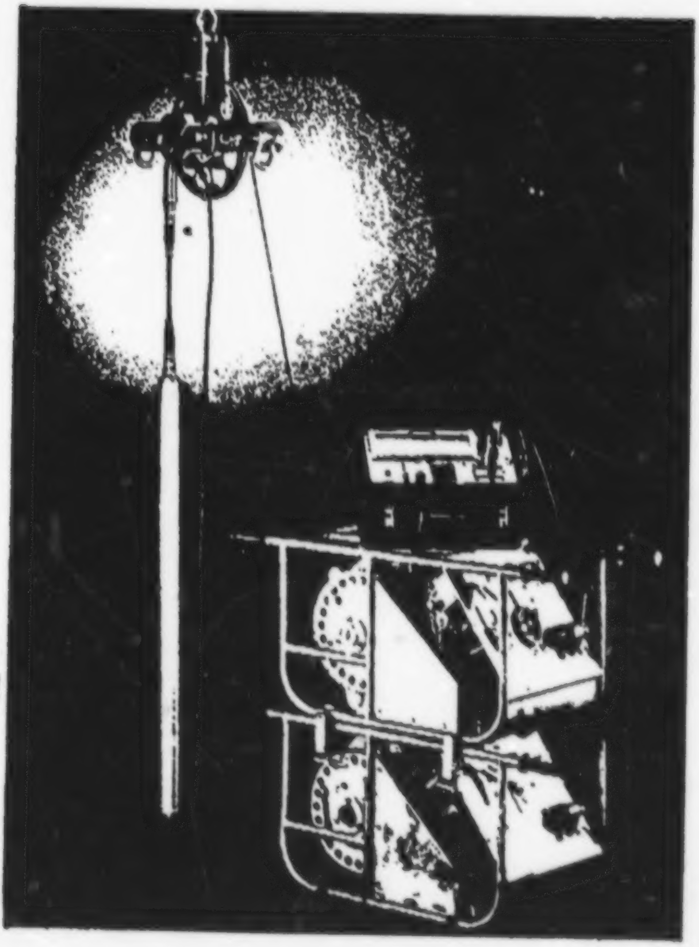
Die Steuerung der Sonden (Ein- und Ausschalten der Sensoren etc.) erfolgt über ein Menüprogramm, das auf einem Display in der Registrierstation dargestellt wird. Auf dem Display können während der Messung ausgewählte Spuren zur Kontrolle der Meßwerte dargestellt werden. Außerdem wird auf dem Display die aktuelle Teufe und die Meßgeschwindigkeit gezeigt.

Das INLOG-System mißt teufenproportional, so daß nach jedem Sample-Intervall (0.5 cm bis 8 cm frei wählbar) ein kompletter Datensatz abgespeichert wird. Die Teufeninformation erhält das INLOG-System von einem Impulsgeber an der Umlenkrolle. Die Anzahl der Sonden, die bei einer Meßfahrt angeschlossen werden können, ist nur durch die maximal zulässige Stromaufnahme (begrenzt durch den Schlagwetterschutz) bestimmt. Die in der Registriereinheit gespeicherten Meßwerte können sowohl seriell als auch parallel auf einen Rechner übertragen werden.

The surface unit contains a microprocessor which receives the transmitted data and stores them in a battery-powered RAM with a capacity of 1 MByte. The microprocessor is also responsible for the communication between the surface unit and the probes. Depending on the probe and on the number of parameters measured, some thousand meters of a borehole can be logged and stored in memory. In addition with the great memory capacity, logs can be run consecutively in several holes on one trip to the mine. Therefore, mobilization costs are substantially decreased.

Communication between the surface unit and the probe (for example, to switch the tool on and off or release the pads of a dipmeter probe) is accomplished by a menu selection display on the surface unit screen. During the measurements, selected data traces can be monitored on the display. In addition the actual depth and logging speed are shown.

Data recording with the INLOG system is depth proportional whereby a complete data set is stored for each sample interval. Sampling rates can be selected between 0.5 cm and 8 cm with a default sampling rate of one centimeter. Timedependent data recording is also available. The data stored in the surface unit may then be transferred in series or parallel to any computer and processed. The number of tools which can be connected concurrently for one run is limited only by the maximum current allowed for the power supply, as designated by the firedamp restrictions.



Das INLOG-System mit Registriereinheit, Stromversorgungs-Modul und Winden (die untere für aufwärtsgerichtete Bohrungen)

The INLOG system with surface unit, power supply module and two winches (the lower winch for upward directed boreholes)

WBK INFORMATION

Daten/Specifications

Registriereinheit/Surface Unit

Länge/Lenght:	398 mm
Breite/Width:	298 mm
Höhe/Height:	203 mm
Gewicht/Weight:	12,5 kg
Prozessor/Processor:	NSC 800
Speicher/Memory:	1 MBytes RAM
Display:	LC Display 460*128 Punkte/Dots
Interface:	VAX/DMA, Centronix, RS 232 Glasfaseroptik zum Anschluß anderer schlagwettergeschützter Geräte Fiber optic to connect other firedamp proofed units
Bedienung/Operation:	über numerisches Keyboard und zwei Funktionstasten by numerical keyboard and two function keys
Analog Eingang/Input:	0–2,5 V
Kabel Driver/Cable driver:	für max. 1200 m einadriges Kabel (oder nach Kundenangaben) for max. 1200 m single conductor cable (or customer specification)
Stromversorgung/ Power supply:	6 * NiCd 4Ah
Betriebsdauer/Operation time:	8 h
Anschlüsse/Connections:	zwei Anschlüsse für digitale Teufenmeßeinrichtungen mit festen Pulsraten (2,5 oder 10 mm) two connections for digital depth measuring systems with predefined pulse rates (2.5 or 10 mm)

Sonden/Probes:

Durchmesser/Diameter:	60 mm
Länge/Length:	1270–1790 mm
Gewicht/Weight:	12,2–17,6 kg
Gamma-Sonde/Gamma probe	
Sensor:	NaJ(TL) 5,08 cm × 2,54 cm/2" * 1" max. Temperatur/max. temp.: 150 °C
Photomultiplier:	Durchmesser/diameter: 2,858 cm/1.125" Aufbau- plus Übertragungszeit kleiner als 100ns rise time + transit time < 100ns
Dichte-Sonde/Density probe	
Sensoren/Sensor:	identisch mit Gamma-Sonde same as in gamma probe
Strahlenquelle/Source:	555 Mbq Cs-137
Abstrahlfenster/ Colimation window:	45 Grad/degrees
Abstände Sensoren: Quelle/ Spacing:	18 cm, 30 cm
Stromversorgungsmodul/ Power supply module:	7*10 Ah NiCd und/and 7*2,5 Ah NiCd
Betriebsdauer/Operation time:	Gamma-Sonde/Gamma tool: 8 h Gamma- und Dichte-Sonde/Gamma + Density: 4 h
Teufenmeßsystem/ Depth measuring system:	Pulsgeber an der Umlenkrolle, 100 Pulse pro Meter deviation wheel, 100 pulses per meter

Ihr Ansprechpartner:

Hans Joachim Rübel · Telefon (02 34) 6 25-4 91
WBK · Postfach 10 27 49 · Herner Str. 45 · D-4630 Bochum
Telefon (02 34) 6 25-0 · Telefax (02 34) 6 25-6 06

DMT

INLOG In-Mine-Logging-System

Surface Unit

Type of protection:	Intrinsic safety 'ib'
Power supply:	5V/600mA (6 x NiCad, each 1.24Ah)
Power consuption: Operating time:	2W (average) 8h (minimum)
Mass storage:	1 Mbyte RAM Example: 1 Mbyte may be used for a logging interval of 300m, recording 16 channels, 16 bit/channel with a resolution of 1 cm. Standard operation: 1 gamma ray channel 12 bit data 2 density channels 16 bit + 12 bit data resolution 1cm in this case the logging interval is about 2000 m.
Graphic dislay:	240 * 128 dots
Interfaces:	16 bit parallel (corresponding to VAX DMA interface) 8 bit Centronics optical RS 232 for in-mine input and output operations
Cable driver:	Designed for 800 m single conducter logging cable and 64k byte/s data rate.
Depth counter 0:	24 bit decimal (9999.99 m, resolution 1 cm)
Depth counter 1:	optional (identical parameters)
Size: Weight:	0.4 m x 0.3 m x 0.2 m 13.5 kg

INLOG In-Mine-Logging-System

Pneumatic Winch

Winch:	pneumatic motor, automatic break, 800 m single conductor logging cable, cable head.
Size:	1 m x 0,45 m x 0.46 m
Weight:	90 kg
Depth rate meter:	
Diameter:	0.72 m
Weight:	38 kg

INLOG **In-Mine-Logging-Systgem**

Gamma ray Sonde

Type of protection: Flameproof enclosure 'EEX dI (ib)'

Power consumption : + 5V/3.5W
- 5V/0.5W

Scintillator: 1" x 2" NaI(Tl)
Photomultiplier: 1-1/8" high temperature bialkali photocatode

Size: diameter 6 cm, length 1.2 m
Weight: 18 kg

The electronic part of the tool contains the DPS-800 downhole processor system and a special interface board. This interface board includes two 16 bit counters, each with an adjustable trigger level. The level adjustment is controlled by the DPS-800 software. (Field calibration without sonde disassembly)

INLOG In-Mine-Logging-System

Density Sonde

Type of protection: Flameproof enclosure 'EEX dI (ib)'

Power consumption: + 5V/4.5W
- 5V/0.5W

Scintillator: 1" x 2" NaI(T1)
Photomultiplier: 1-1/8" high temperature bialkali photocatode
Spacing: Cs-137 Source/ first detector 150 mm
first detector/ second detector 300 mm

Size: diameter 6 cm, length 1.7 m
Weight: 25 kg

The electronic part of the tool contains the DPS-800 downhole processor system and a special interface board. This interface board includes four 16 bit counters, each with an adjustable trigger level. The level adjustment is controlled by the DPS-800 software. (Field calibration without sonde disassembly)

INLOG In-Mine-Logging-System

Downhole Power Supply

Type of protection:	Flameproof enclosure EEX dI (iB)
Output:	+ 5V/2A - 5V/300mA
Akkumulator:	7 NiCad 10Ah 7 NiCad 2.5Ah

The power supply is automatically turned on by receiving data from the surface unit. Each sonde is able to turn off the power supply by setting a power off signal.

APPENDIX A5.3

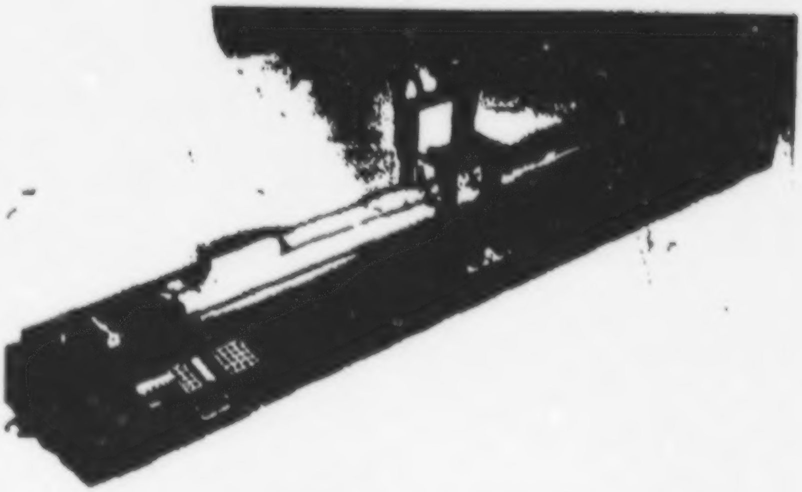
STRATASNOOP™ SYSTEM

Coran

The Coran borehole core analyser measures bulk density and grade of "binary" type (eg. coal, iron ore, uranium ore) geological materials. Coran was developed by the Division of Mineral Physics for field use, to provide more comprehensive, accurate and timely information for the exploration dollar and thereby reduce exploration cost.

Density is determined from the measurement of the Compton linear-attenuation coefficient, and grade from the photoelectric mass-absorption coefficient, utilising the attenuation of high (more than 300 keV) and low (less than 100 keV) gamma-ray beams transmitted through the sample. The radioisotope sources and the collimator are located below the specimen rack. The NaI crystal gamma-ray detector and core diameter sensor are above the sample. Drill core identification data are entered and the microprocessor-controlled analysis and recording system provides an annotated print-out of logging results. The technique is non-destructive and can provide an immediate log of core at the borehole, so that exploration decisions can be taken on the spot.

Coran is available from the licensee, Mineral Control Instrumentation Pty Ltd of Adelaide, South Australia.



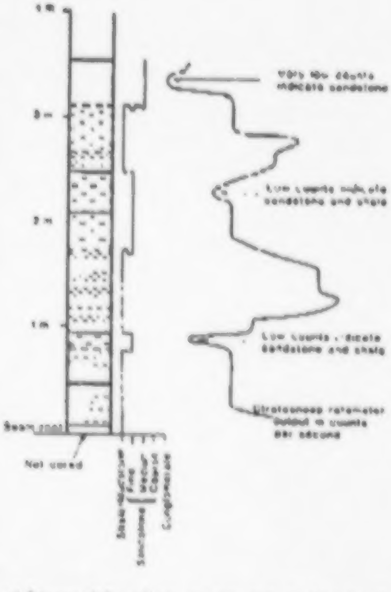
Coran provides non-destructive borehole core analysis in the field, giving accurate and timely information. Exploration costs can be minimised by the use of this system, developed by the Division of Mineral Physics and licensed to Mineral Control Instrumentation Pty Ltd, Adelaide, South Australia.

Stratasnoop

In some underground mines the roof is mudstone or shale, overlain by sandstone. The sandstone has very good bolt-anchoring characteristics, compared to the mudstone or shale, so it is important to determine whether a bolthole reaches the sandstone layer. The Division of Mineral Physics has developed a bolthole logger, Stratasnoop, to detect mudstone and delineate the boundary between mudstone and sandstone.

This instrument monitors natural gamma rays emitted from trace amounts of the radio-isotopes potassium, uranium and thorium in the mudstone. Sandstone has a relatively low natural gamma-ray activity compared to mudstone or shale, so can be easily detected. Stratasnoop is licensed to ETP Pty Ltd in Sydney, New South Wales.

Stratasnoop can be extended to 12m yet easily folds into a carrying case the size of a large briefcase. The digital read-out display, with flashing LED indicator, is mounted on a clipboard holding field record sheets. This bolthole logger was developed by the Division of Mineral Physics and is licensed to ETP Pty Ltd, Sydney, NSW.



Alongside this core of a logged bolthole in the Bulli Seam is an interpretation of the core, showing the sandstone content of the various strata. The rate meter output from Stratasnoop, in counts per second, identifies the sandstone layers by their low count rates.

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ATTN: STEVE COTTEN
CONOCO INC.

1ST JUNE 1984

ETP'S ADDRESS IS:

31 HOPE STREET,
ERMINGTON, N.S.W. 2115

TEL. SYDNEY 858-5122 (9-011-61-2-858-5122)

I HAVE NO EXPERIENCE WITH THE INSTRUMENT BUT I DID HEAR A TALK ON IT BY K.G. MCCRACKEN AND P.J. MATHEW OF THE COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION (CSIRO) DIVISION OF MINERAL PHYSICS, WHO DEVELOPED THE INSTRUMENT.

THE FOLLOWING IS TAKEN FROM THE ABSTRACT OF THEIR PAPER:-

A BOLT-HOLE PROBE AND A COAL BOREHOLE-CORE ANALYSER HAVE BEEN D DEVELOPED BY THE C.S.I.R.O. DIVISION OF MINERAL PHYSICS AS PART OF A MAJOR PROGRAM IN THE APPLICATION OF NUCLEAR TECHNIQUES TO EXPLORATION, EXTRACTION AND QUALITY CONTROL IN THE MINING INDUSTRY.

IN SOME AUSTRALIAN UNDERGROUND COAL MINES, THE EXPOSED ROOF IS INCOMPETENT MUDSTONE OR SHALE OVERLAIN WITH SANDSTONE HAVING EXCELLENT BOLT ANCHORING CHARACTERISTICS. IT IS NECESSARY THEREFORE TO DETERMINE WHETHER THE BOLT HOLES HAVE PENETRATED THE SANDSTONE STRATUM. THE BOLT-HOLE PROBE, KNOWN AS ''STRATASNOOP'', MEASURES THE DEPTH OF THE MUDSTONE AND DELINEATES THE BOUNDARY BETWEEN MUDSTONES AND SANDSTONE. THE DEVICE CONSISTS OF A CSI(NA) GAMMA-RAY DETECTOR AND ASSOCIATED ELECTRONIC EQUIPMENT. THE MUDSTONE IS DETECTED BY ITS HIGH NATURAL GAMMA-RAY ACTIVITY CAUSED BY THE PRESENCE OF TRACE AMOUNTS OF K, U AND TH. IN THE SAME GEOLOGICAL HORIZON, THE SANDSTONE IS CHARACTERISED BY ITS RELATIVELY LOW GAMMA-RAY ACTIVITY.

THE ''STRATASNOOP'' PROBE IS 25MM IN DIAMETER AND IS PROVIDED WITH A SERIES OF FIBREGLASS EXTENSION RODS. EXTENSIVE TESTS IN UNDERGROUND COAL MINES HAVE DEMONSTRATED THAT THE INSTRUMENT CAN LOCATE THE MUDSTONE/SANDSTONE INTERFACT TO +/- 50MM. A SYDNEY-BASED COMPANY HAS BEEN LICENCED TO MANUFACTURE THE INSTRUMENT.
YOUR ENQUIRY SHOULD BE DIRECTED TO DR. ROYDEN LAKE.

THE INSTRUMENT IS STILL AT PROTOTYPE STAGE AND WILL BE TRIED OUT IN NSW MINES OVER NEXT FEW MONTHS BEFORE A COMMERCIAL PRODUCT IS OFFERED.

REGARDS
A. FAY.

Bolt-hole and borehole-core logging instrumentation

K.G. McCracken and P.J. Mathew
C.S.I.R.O. Division of Mineral Physics,
P.O. Box 124, PORT MELBOURNE, VIC. 3207

ABSTRACT

A bolt-hole probe and a coal borehole-core analyser have been developed by the C.S.I.R.O. Division of Mineral Physics as part of a major program in the application of nuclear techniques to exploration, extraction and quality control in the mining industry.

In some Australian underground coal mines, the exposed roof is incompetent mudstone or shale overlain with sandstone having excellent bolt anchoring characteristics. It is necessary therefore to determine whether the bolt holes have penetrated the sandstone stratum. The bolt-hole probe, known as "Stratasnoop", measures the depth of the mudstone and delineates the boundary between mudstones and sandstone. The device consists of a CsI(Na) gamma-ray detector and associated electronic equipment. The mudstone is detected by its high natural gamma-ray activity caused by the presence of trace amounts of K, U and Th. In the same geological horizon, the sandstone is characterised by its relatively low gamma-ray activity.

The "Stratasnoop" probe is 25 mm in diameter and is provided with a series of fibreglass extension rods. Extensive tests in underground coal mines have demonstrated that the instrument can locate the mudstone/sandstone interface to ±50 mm. A Sydney-based company has been licenced to manufacture the instrument.

The borehole-core analyser is a portable instrument for the non-destructive and contactless measurement of density and ash content of coal borehole cores in 5 mm sections. The analyser is based on a gamma-ray attenuation technique and consists of a high-energy and a low-energy gamma-ray source and a NaI(Tl) gamma-ray detector and associated electronics. The borehole core is placed in the path of a well collimated gamma-ray beam from the sources, and the detector measures the attenuation of the gamma-rays. The attenuation experienced by the high-energy gamma-rays is a measure of the density of the bore-hole core section. The ash content is derived from the attenuation experienced by both the high-energy and the low-energy gamma-rays.

The laboratory measurements on simulated borehole cores made of coal pellets of accurately known ash content and density showed an accuracy of 1% ash and 0.01 g/cm^3 respectively for coals from the same area. The radiation sources are well shielded in the lead housing. The radiation level in any accessible part of the instrument is comparable to the natural radioactivity from the environment.

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INTRODUCTION

Research and development in the application of nuclear geophysical techniques to exploration, extraction and quality control in the mining industry is one of the major programs carried out by the C.S.I.R.O. Division of Mineral Physics. The principal nuclear geophysical techniques studied under this program are the natural gamma, gamma-gamma, neutron-gamma and neutron-neutron methods. Several instruments developed under this program are being licenced to Australian companies for manufacture and sale.

A bolt-hole probe and a coal borehole-core analyser have been developed recently by the Division, these instruments form the subject matter of this paper. The bolt-hole probe, which is based on the detection of natural gamma radiation, is used to determine the location of the interface between mudstone and sandstone in bolt holes drilled for roof support in underground mines. A gamma-ray transmission technique is employed in the borehole-core analyser to measure the density and ash content of coal borehole cores over 5 mm length intervals.

THE BOLT–HOLE PROBE

In most underground operations, rock bolts are needed to support the roof of the mine. These steel bolts, which are usually about 25 mm in diameter and several metres long, are inserted into holes drilled in the rock and anchored in rock strata with suitable stress-bearing capabilities. In some Australian underground collieries the exposed roof is mudstone or shale of relatively low strength overlain by a sandstone that has excellent bolt-anchoring characteristics. It is therefore important to ensure that the bolt holes have penetrated the sandstone. The thickness of mudstone varies in different areas and there has previously been no accurate way of measuring this parameter. Estimating the thickness of the mudstone by examining chips from the bolt hole is messy, time-consuming and inaccurate. The bolt-hole probe, known as "Strata-snoop", overcomes this problem and ~~can be used~~ to locate the interface between mudstone and sandstone with a high degree of accuracy.

Principle of the Bolt-hole Probe

The operation of the bolt-hole probe is based on the measurement of natural gamma radiation (Lynch, 1962). Virtually all geological strata contain naturally occurring radioactive elements such as uranium, thorium and potassium in trace quantities. The presence of these elements can be detected with a radiation detector sensitive to the gamma-rays they emit.

The amount of natural radioactivity in a rock formation depends on its composition and geological history. Clay minerals have high absorption and ion-exchange capabilities that result in preferential accumulation of the above radioactive elements. Thus, mudstone and shale, which contain a high proportion of clay, tend to have significantly more natural radioactivity than sandstone, while coal has very little intrinisic radioactivity. The amount of radioactivity emitted from such formations can be determined with the aid of a sensitive gamma-ray detector and associated electronic equipment, and the position of the interface between mudstone and sandstone can be determined from changes in the radiation level recorded.

Technical Details of the Bolt-hole Probe

The prototype bolt-hole probe consists of a CsI(Na) scintillation detector and photomultiplier 50 mm long x 18 mm in diameter, a high-voltage power supply, an amplifier and a ratemeter. A schematic diagram of the probe and associated equipment is shown in Figure 1.

Manual readings!

The CsI(Na) detector was chosen for its high efficiency and its resistance to mechanical shock. The photomultiplier requires stabilised power for consistent results, and a high-voltage power supply was specially designed for this purpose. The power supply provides an output of 1300 V, which regulated to ± 0.01% over the full range of the battery voltage used (10 V to 14 V).

The probe is encased in a 25 mm diameter stainless ~~steel tube.~~ The high-voltage power supply is also incorporated in this tube in order to make the instrument safe to use in underground mines. The probe is powered by lead-acid gel cells that provide 12 hours of operation, and a small battery charger is provided with the unit. The ratemeter, the power cells and the battery charger are enclosed in a leather case that hangs from the operator's neck. The probe has been designed in such a way that a gamma-ray source can easily be incorporated in order to turn the instrument into a gamma-gamma density probe.

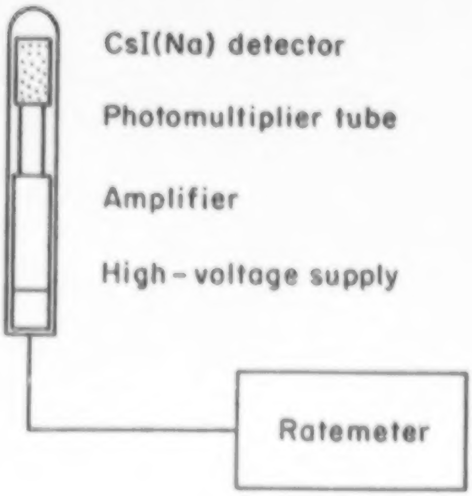

Figure 1 *Schematic diagram of the bolt-hole probe.*

Fibreglass extension rods 1.8 m long are used to push the probe into the bolt hole. A series of readings, each over a period of 10 to 15 sec. is taken with the probe at various positions in the hole. A scale on the fibreglass rods indicates the position of the probe at the time of each reading, and the point at which the probe's response changes significantly is taken as the interface between the two contrasting rock types.

Field Test of the Prototype

A prototype of the probe was field-tested for six months in order to evaluate its applicability and reliability for routine logging of roof bolt holes in underground mines. Typical logs of selected bolt holes in an underground coal mine working the Bulli Coal in the Southern Coalfield, N.S.W., are shown in Figure 2.

These holes had been drilled to a depth of 1.8 m. In holes 106 and 107, the boundaries between mudstone and sandstone are clearly delineated at a depth of a little over 1 m. The natural gamma radiation level of the mudstone in these holes is nearly twice that of the sandstone. The mudstone extends over nearly the full depth of holes 3, 5 and 7, but no mudstone is visible in hole 101. Low radiation levels were recorded near the start of holes 99 and 100 because of the presence of

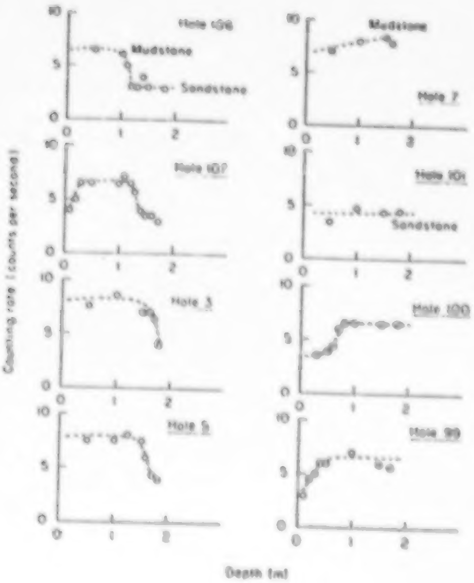

Figure 2 *Typical logs of bolt holes.*

carbonaceous shale, which has very little radioactivity. However, the remainder of each of these holes penetrated only mudstone.

The field tests showed that five or six readings were usually sufficient to locate the mudstone/sandstone interface to within 50 mm. It should be noted that the probe can identify not only sandstone and mudstone, but also any other interface between rock types that has a characteristic contrast in natural gamma radiation level.

The field tests proved the usefulness and reliability of the device as well as the robustness of its mechanical and electronic components. The tests also suggested a few design modifications for improved handling and performance.

Such modifications include:

(a) incorporation of a digital integrating meter to determine more accurately the probe's responses;

(b) redesign of the extension rods and incorporation of a continuous cable on a recoil winder to eliminate the need for switching off the probe when extension rods are added or removed;

(c) reduction of the length of the probe, and provision of a carring pouch.

The instrument has now been licenced to a Sydney-based company (ETP Pty Ltd, St Leonards, N.S.W.) for manufacture and sale.

THE BOREHOLE-CORE ANALYSER

Very few instrumental techniques have been available to evaluate non-destructively coal borehole cores for geological, technical and commercial information. The development of x-radiography of borehole cores (Jones, 1970) has been a significant contribution in meeting an important need in this field. X-radiography provides a permanent record of the nature and distribution of mineral matter in coal in a qualitative fashion. The borehole-core analyser has been developed to determine quantitatively the density and ash content of borehole cores and broken pieces of coal, either in the field or in the laboratory.

Principle of the Borehole-core Analyser

The density and ash determinations are based on measurements of the Compton linear-attenuation coefficient and the photoelectric mass-absorption coefficient of the material (Fushimi, 1968; Mathew, 1976). These measurements utilise the attenuation experienced by a "high-energy" gamma-ray beam ($>$300 keV) and a "low-energy" gamma-ray beam ($<$100 keV) when transmitted through the coal sample.

In a narrow-beam geometry, the attenuation experienced by the high-energy gamma-ray beam is related to the density of the material through which it passes. The density ρ, is given by

$$\rho = \frac{a}{d} - \frac{b \ln I_1}{d} - c$$

Where I_1 is the intensity of the transmitted beam, d is the thickness of the material, and a, b and c are constants. The ash content of the sample is derived from the attenuation experienced by both the high-energy and the low-energy gamma-ray beams (Fushimi, 1968) and is given by

$$y = AT_r - B$$

where y is the percentage of ash in the sample, A and B are constants, and

$$T_r = \frac{\ln (I_2/I_{02})}{\ln (I_1/I_{01})}$$

where I_{01} and I_1 are the incident and transmitted intensities of the high-energy beam and I_{02} and I_2 are the incident and transmitted intensities of the low-energy beam. T_r is termed the two-beam ratio.

Technical Details of the Borehole-core Analyser

A schematic diagram of the analyser and the associated electronic equipment is shown in Figure 3. The analyser consists of:

(a) a 10 mCi ^{137}Cs source to provide the "high-energy" gamma-ray beam (662 keV), and a 50 mCi ^{241}Am source to provide the "low-energy" gamma-ray beam (60 keV);

(b) a detector assembly consisting of a NaI(Tl)

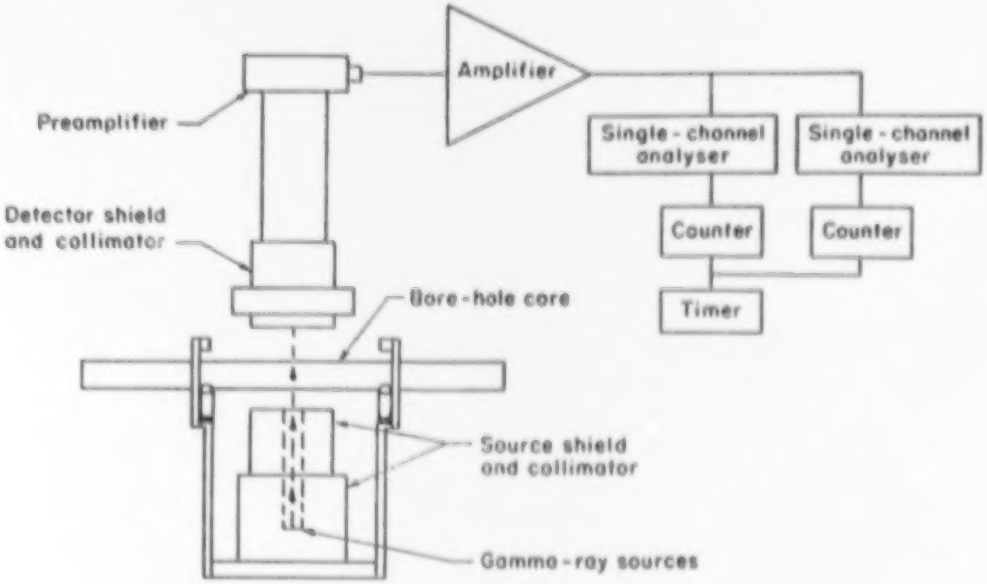
Amplifier
Preamplifier
Single - channel analyser
Single - channel analyser
Detector shield and collimator
Counter
Counter
Bore - hole core
Timer
Source shield and collimator
Gamma - ray sources

Figure 3 *Schematic diagram of the coal borehole-core analyser.*

detector 51 mm x 51 mm in size, a photomultiplier and a preamplifier;

(c) a nuclear instrumentation module consisting of a stabilised amplifier, two single-channel analysers and two timer-counter units;

(d) a core rack on rollers for positioning the drill cores in the gamma-ray beam;

(e) a programmable calculator interfaced with the timer-counter units.

The gamma-ray sources are enclosed in heavy lead shielding, which also acts as a collimator (5 mm wide x 15 mm long) to provide a parallel beam of gamma-rays. The NaI(Tl) detector is well shielded and collimated to accept the gamma-ray beam.

The signals from the detector assembly are fed into the timer-counter units through the amplifier and the single-channel analysers. One analyser is adjusted to accept the "high-energy" signals, the other the "low-energy" signals. The amplifier is stabilised on the full energy peak of the ^{137}Cs source. The programmable calculator determines the density from the "high-energy" gamma-ray count and the diameter of the drill core by means of a calibration equation. The ash content is calculated from the "high-energy" and "low-energy" gamma-ray counts by means of another calibration equation.

In the work reported here, every measurement implies a core section 5 mm wide because the width of the gamma ray beam can be varied to provide the required spatial resolution.

Laboratory Tests of the Borehole-core Analyser

The analyser was subjected to laboratory tests with coal samples having accurately known relative densities and ash contents. The pulverized samples were either put in plastic vials or pelletized with a hydraulic press to form 50 mm diameter x 50 mm long cylinders to simulate sections of core. The densities of the simulated core sections were determined from their masses and physical dimensions. The coal samples were collected from nine different seams and locations in New South Wales in order to cover a wide range of ash contents and ash compositions. The ash contents of the samples varied from 6% to 55%.

During measurement, each sample was placed on the core rack and positioned in the gamma-ray beam. An intergration time of 100 sec was used to obtain the intensities of the "high-energy" and "low-energy" gamma-ray beams transmitted through the sample. Counting for the same duration, without the sample, provided the intensities of the incident gamma-ray beams. From these two counts, the density and the ash content of the sample were derived.

Results and Discussion

Standard regression analysis techniques were used to establish the relationship between the attenuation experienced by the gamma-ray beams and the ash content and density of the coal samples. The relationship between the ash content and

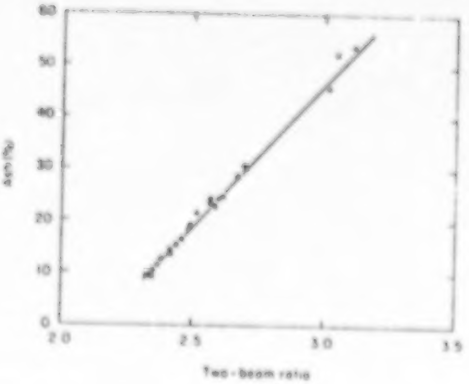

Figure 4 *Relationship between the ash contents and the two-beam ratios of coal samples from the same region.*

the two-beam ratio was established with the general equation

$$y = a + bx$$

where y is the percentage of ash (on a dry basis), a and b are constrants and x is the two-beam ratio (T_r). Regression analysis of data for 23 coal samples from a single colliery near Wollongong yielded the equation

$$y = -123.980 + 57.186x$$

with a standard deviation of 1.0% ash for a single measurement. The ash contents of these samples ranged from 9% to 55%, and the relationship between the percentage of ash and the two-beam ratio is illustrated in Figure 4. Exclusion of data for high-ash samples (>40% ash) yielded the equation

$$y = -124.206 + 57.282x$$

with the standard deviation reduced to 0.7% ash. Regression analysis of data for 41 coal samples obtained from nine different seams and locations in N.S.W. yielded the equation

$$y = -116.501 + 53.59x$$

with a standard deviation of 2.7% ash for a single measurement. This increase in standard deviation was evidently caused by the wide variation in ash composition. Thus, the instrument must be separately calibrated for different coals from different areas.

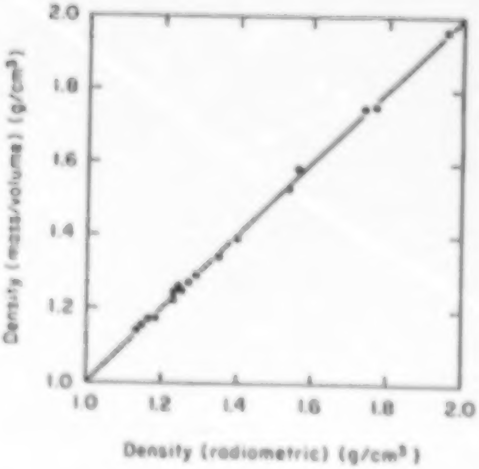

Figure 5 *Comparison of density (mass/volume) and density (radiometric) for pelletized coal samples.*

The regression equation obtained for the relationship between the density, the gamma-ray counts and the sample thickness was

$$\rho = 195.12x - 14.25y - 0.025$$

where x = 1/diameter and y = ln (gamma-ray counts)/diameter. The standard deviation of ρ was 0.01 g/cm³ for a single measurement. A comparison of the densities of the pelletized coal samples, as determined from their masses and volumes, with the radiometrically determined densities is shown in Figure 5.

An example of the ash content and density of a 1 m core section is shown in Figure 6. These logs show the close correlation between the ash content and the density of coal, as well as the distribution of plies and bands in fine detail. Several thin dirt bands, which were not visable in the core section, are clearly visible in the logs. Logs with such details could assist in accurately subdividing cores for destructive testing, seam correlation, coal reserve estimation and information on coal washability. The analyser is currently undergoing detailed studies to evaluate its potential in coal exploration and mining.

Radiation Safety

The radiation sources are well shielded in the lead housing of the analyser, and radiation leakage is negligible. The radiation level in any accessible part of the instrument is comparable to the natural background radiation level from the environment.

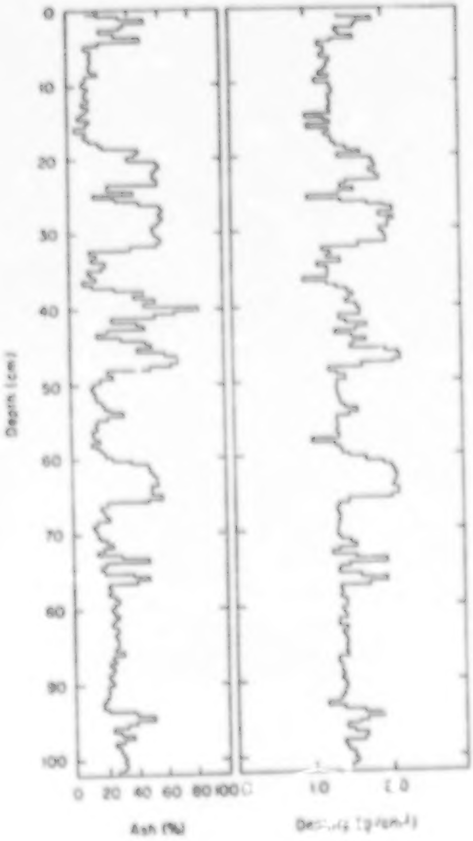

Figure 6 Sample log of a 1 m coal core length.

CONCLUSIONS

Two instruments based on nuclear geophysical techniques have been developed for use in exploration and mining by the coal-mining industry. The bolt-hole probe is based on the measurement of natural gamma radiation and is capable of determining the mudstone/sandstone interface in bolt holes drilled for roof support in underground coal mines. The instrument is simple in design and operation, and it is compatible with the requirements of the N.S.W. Department of Mines for use in underground coal mines. Extensive field tests of the probe have proved the usefulness and reliability of the device as well as the robustness of the electronic and mechanical components. Usually, five or six readings of the probe inside a bolt hole will determine the location of the mudstone/sandstone interface to ± 50 mm. The field tests revealed a few minor design modifications that could improve the handling and performance of the instrument. The bolt-hole probe has been licensed to a Sydney-based company for manufacture and sale.

The coal borehole-core analyser, which is based on gamma-ray transmission, is used for non-destructive and contactless measurement of the densities and ash contents of coal bore-hole cores in 5 mm sections. Laboratory measurements on simulated core sections made of pelletized coal or pulverised coal in plastic vials showed an accuracy of 1% ash and 0.01 g/cm³ for coal from the same area. The accuracy of the ash determinations decreased to 2.7% ash for coal samples from different regions because of variations in the mineral content. For accurate ash determinations, coals from different areas need separate calibrations. A sample log of the ash content and the density of a 1 m core section shows the distribution of plies and bands in fine detail. The analyser is currently undergoing detailed evaluation of its potential in coal exploration and mining.

ACKNOWLEDGEMENTS

Messrs D. Coward and B. Maher were responsible for the development of the bolt-hole probe. The assistance of Messrs R.G. Wilson and W.A. Williams of Australian Iron and Steel Pty Limited is gratefully acknowledged. Support for the work on the coal borehole-core analyser was provided under the National Energy Research, Development and Demonstration Program administered by the Australian Department of National Development.

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